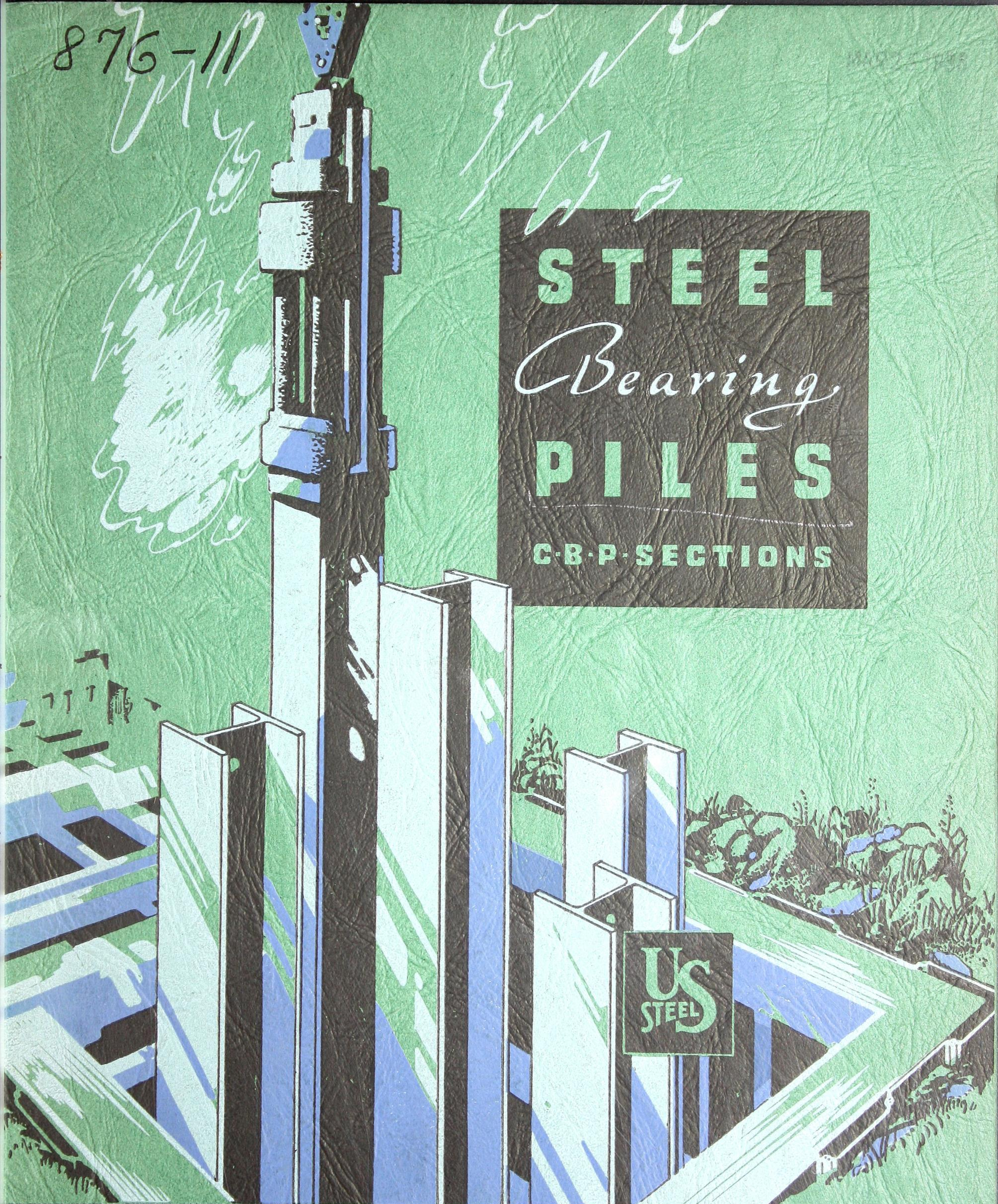
STEEL *Bearing* PILES

C·B·P·SECTIONS



CARNEGIE STEEL COMPANY · PITTSBURGH

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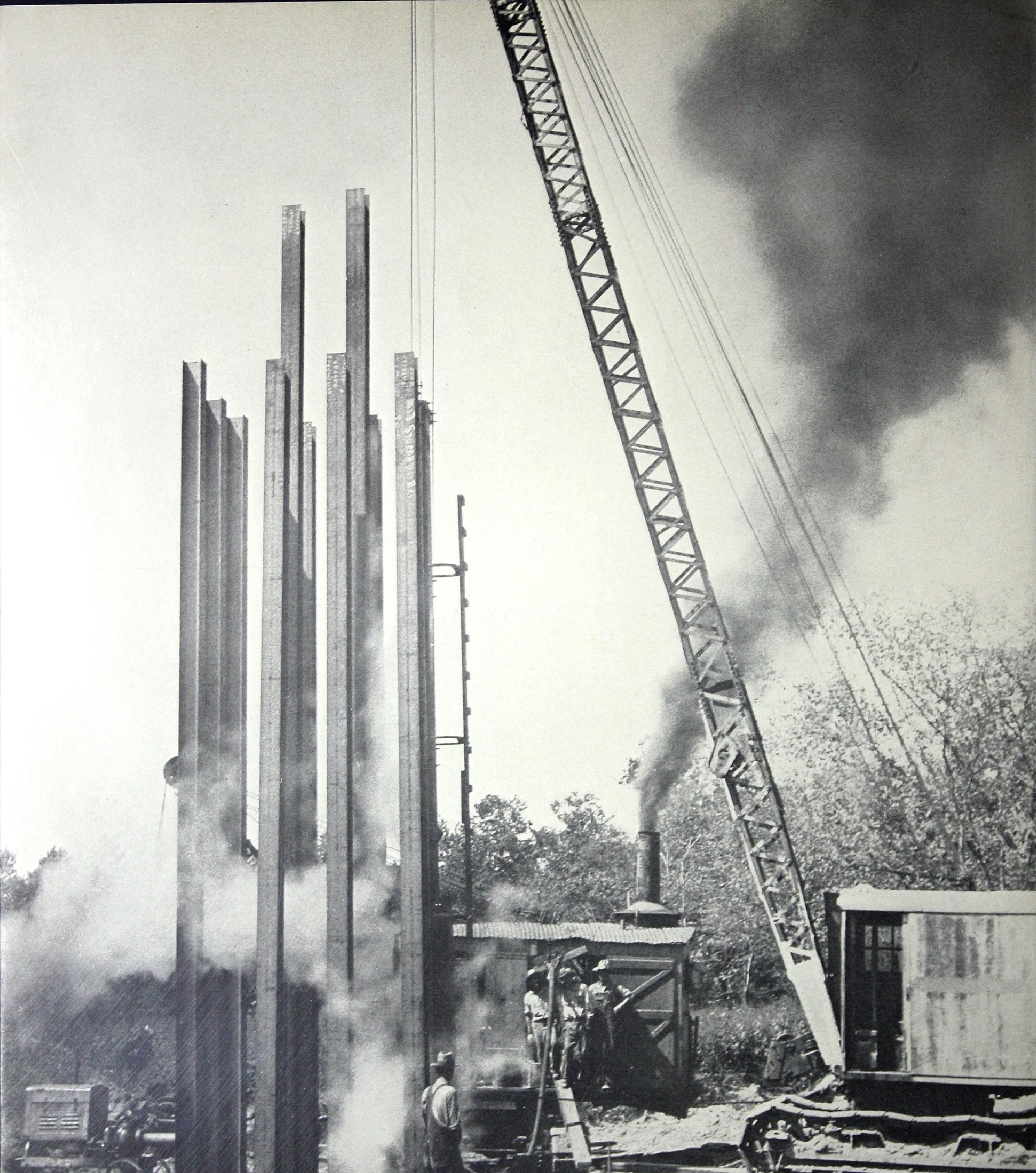

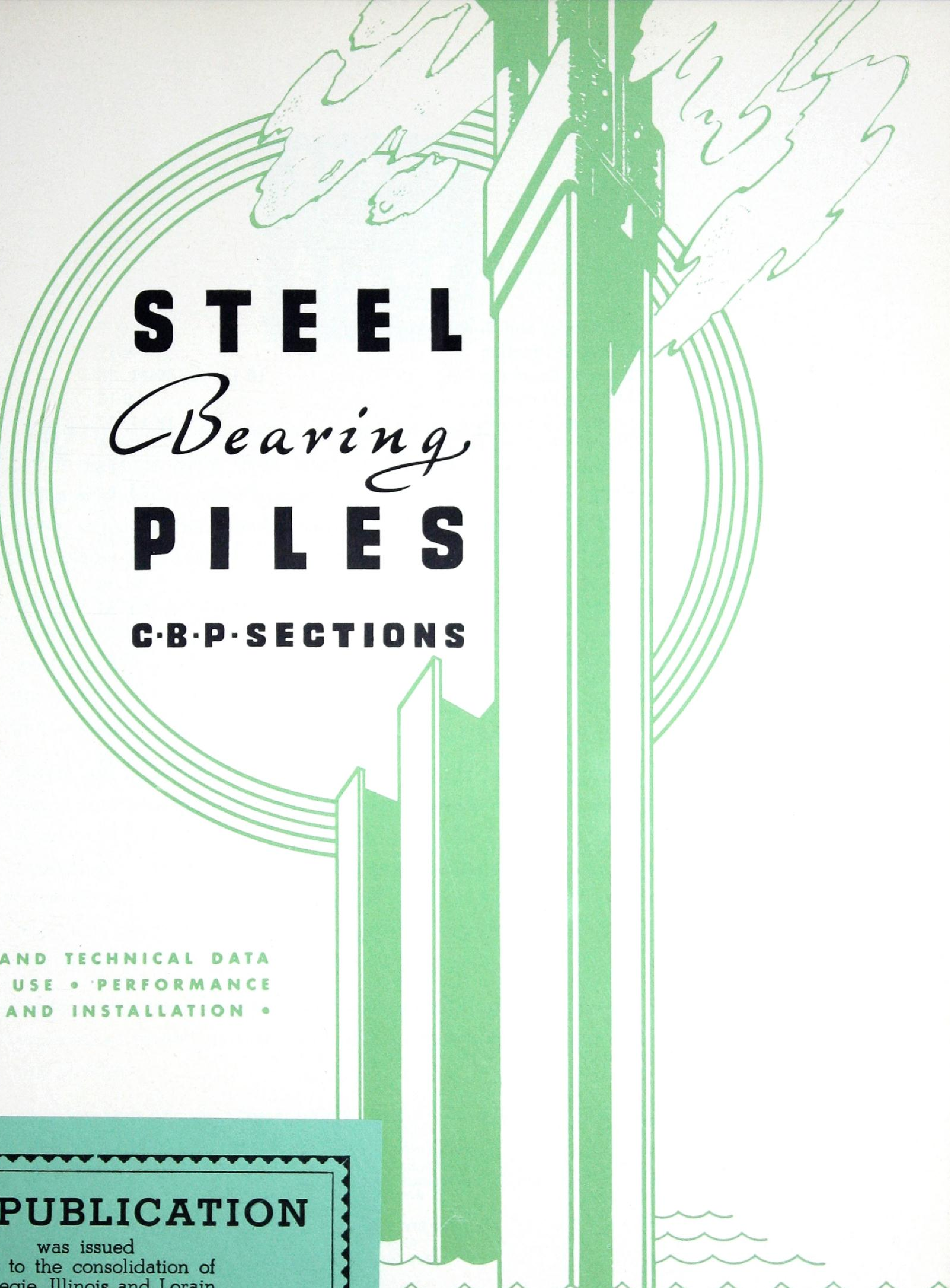

STEEL *Bearing* PILES

C·B·P·SECTIONS

GENERAL AND TECHNICAL DATA
ON THEIR USE • PERFORMANCE
• DESIGN AND INSTALLATION •

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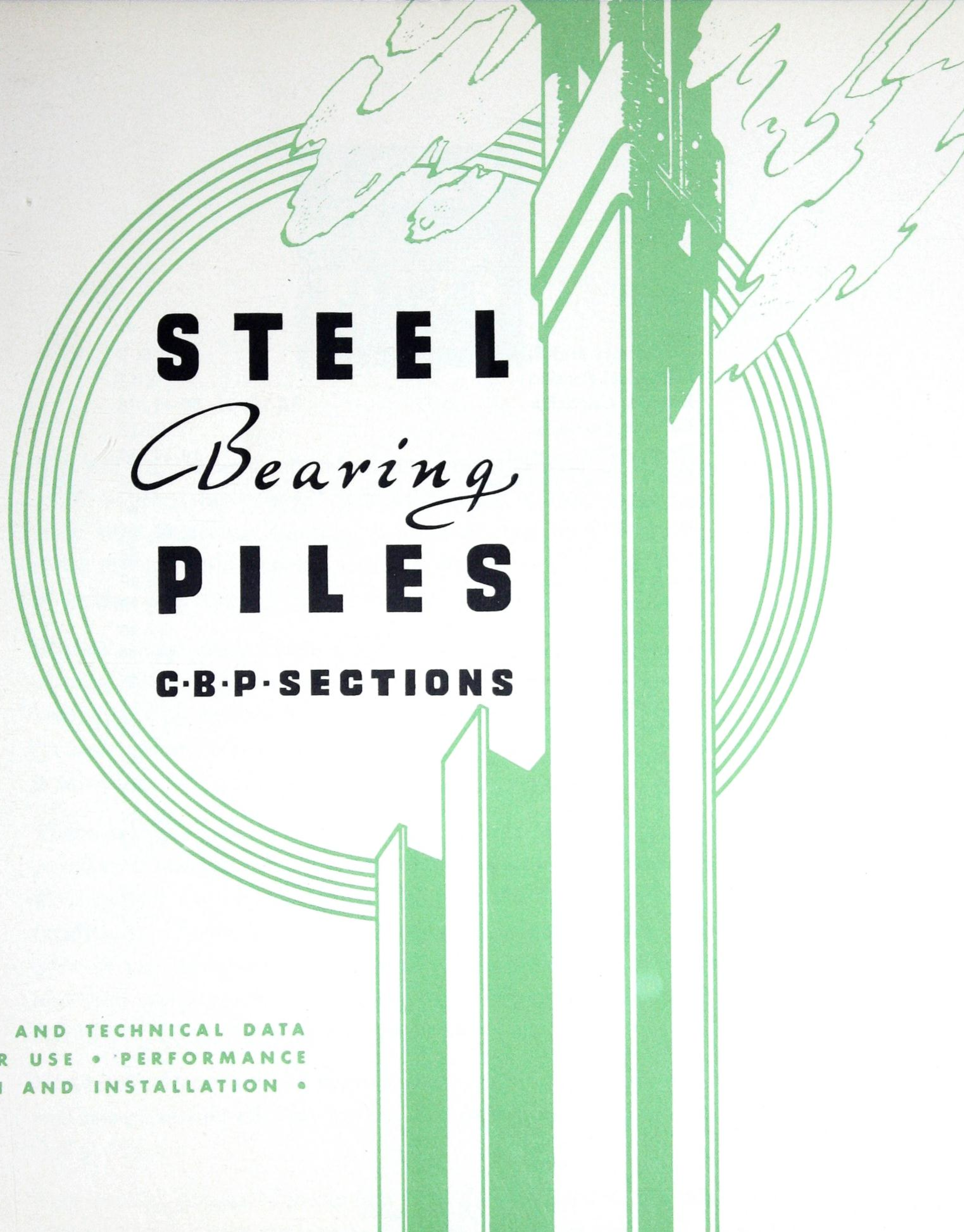

STEEL *Bearing* PILES

C·B·P·SECTIONS

GENERAL AND TECHNICAL DATA ON THEIR USE • PERFORMANCE • DESIGN AND INSTALLATION •

CARNEGIE STEEL COMPANY • PITTSBURGH

ILLINOIS STEEL COMPANY • CHICAGO

United States Steel Corporation Subsidiaries

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STEEL *Bearing* PILES

C·B·P·SECTIONS

WHILE various individual and combinations of different steel sections have been used as bearing piles upwards of forty years with entire satisfaction, the use of steel for this purpose was given considerable impetus through the introduction of the H type of section over twenty-five years ago.

Within recent years, there has been a growing trend toward the use of wide flange CB sections for bearing piles. Their use has been accelerated by the important disclosure that steel pile sections in soil for over twenty-five years show that the loss of metal from corrosion is too slight to be of any consequence.

There are hundreds of bridges in the Middle West supported by exposed steel bearing piles which have been in service for periods ranging from twenty-five to thirty-eight years, which are still in satisfactory condition. During the last few years, thousands of steel piles have been driven to support the piers of a number of important bridges, and their use is gradually extending to every class of work for which any types of bearing piles are adaptable.

Heretofore, there has not been available from any one source a comprehensive record of tests and of the past uses and applications of this product.

This booklet presents for the first time an extensive review of the use of steel bearing pile sections in the past, as well as data and illustrations of the current practice in the design and use of the new steel CBP section bearing piles.

STEEL *Bearing* PILES

C·B·P·SECTIONS

ECONOMIES
IN USING "CBP" SECTION STEEL BEARING PILES

★ Greater capacity per pile. Permits the use of fewer piles and reduces size and expense of cofferdams, amount of excavation for footings, and volume of other materials in the pile cap or pier.

★ Speed in driving. The rigidity and stiffness of steel due to its high modulus of elasticity insures that nearly all of the energy of the pile driving ram is transmitted to the pile and its full force is available for securing penetration. As experience has shown, steel piles penetrate much more easily and rapidly than those of other materials.

★ Less space required for storage and shipping.

★ Plain lengths as shipped from the mill are readily handled. Bearing piles will be furnished with handling holes at one or both ends if specified or ordered.

★ Withstand rough handling. They are not subject to splitting, bruising, or other damage under rough handling. They require no special rig of slings or delicately adjusted handling and placing equipment.

★ Elimination of jetting. It has not been found necessary to resort to jetting in order to secure adequate penetration of rolled steel section bearing piles.

★ Ease of splicing in field when necessary to secure greater length.

★ Possible to drive to desired penetration under very severe conditions where no other type of bearing pile could be used.

★ High resistance to horizontal loads at and above the ground line in trestle bent construction. Stiffness is not limited by size of piles available, for with steel the number of piles per bent can be fixed, and the sections designed to fit conditions. This permits the use of fewer large piles whose cost of driving with adequate equipment is little, if any, more than the cost of driving small piles.

SPECIAL ADVANTAGES

OF "CBP" SECTIONS AS STEEL BEARING PILES

Rolled steel sections may be used wherever bearing piles are required to sustain a structure. They offer special advantages and are particularly adaptable under the following conditions:

★ Where it is impossible to secure sufficient penetration with piles made from other material. This may be where considerable penetration through hard-driving material, such as sand and gravel, is required in order to reach sufficient depth to prevent undermining by scour or wash of water at bridge piers located in rapidly flowing rivers; or where there is danger of undermining the foundations due to later possible excavation carried to greater depths for adjacent structures.

★ Where they can be driven through loose, unstable fill or soil to a relatively hard strata where their full strength as a column can then be developed.

★ Where extremely great penetration is necessary to secure adequate bearing capacity, such as under conditions encountered at the site of deep alluvial deposits, or where there is considerable depth of unstable material which must be penetrated before suitable load carrying strata are encountered.

★ Where close spacing of piles is required to carry very heavy superimposed loads, steel piles can be driven with a much smaller resultant displacement or disruption of the soil, thus permitting the driving of very long lengths with higher ultimate carrying capacity for individual or for groups of piles. Also, due to higher capacity per pile, spacing for given load may be increased with still further reduction of soil disturbance.

★ Where the pile sections are required to act both as bearing piles as well as the columns of trestle bents, supporting either railway or highway bridges, or viaducts.

★ In the reconstruction of existing pile bents, steel piles may be driven in the relatively small areas remaining between existing piles, which permits the replacement of a timber and pile trestle bent structure with steel without interruption or delay to traffic.

★ Where piles must be driven very close to adjoining structures. The small displacement of earth in both vertical and lateral directions during the driving of steel piles reduces the possibility of disturbance to adjacent structures.

★ Where very high unit loads per pile must be developed.

★ In earthquake areas, foundation designs can be made to take advantage of the extremely high bending strength of steel piles. Their use will permit the development of required resistance to lateral forces.

★ Where piles are subject to attack and destruction by borers, insects, or other organisms, such as limnoria, teredo, and termites.

HISTORY OF STEEL BEARING PILES

In the early nineties, hundreds of bridges were built in the territory between the Mississippi River and the Rocky Mountains, of the type known as "bedstead bridges." These structures were supported by steel section piles driven either singly or in pairs at the corners of the bridge, and at various other points along the abutment walls.

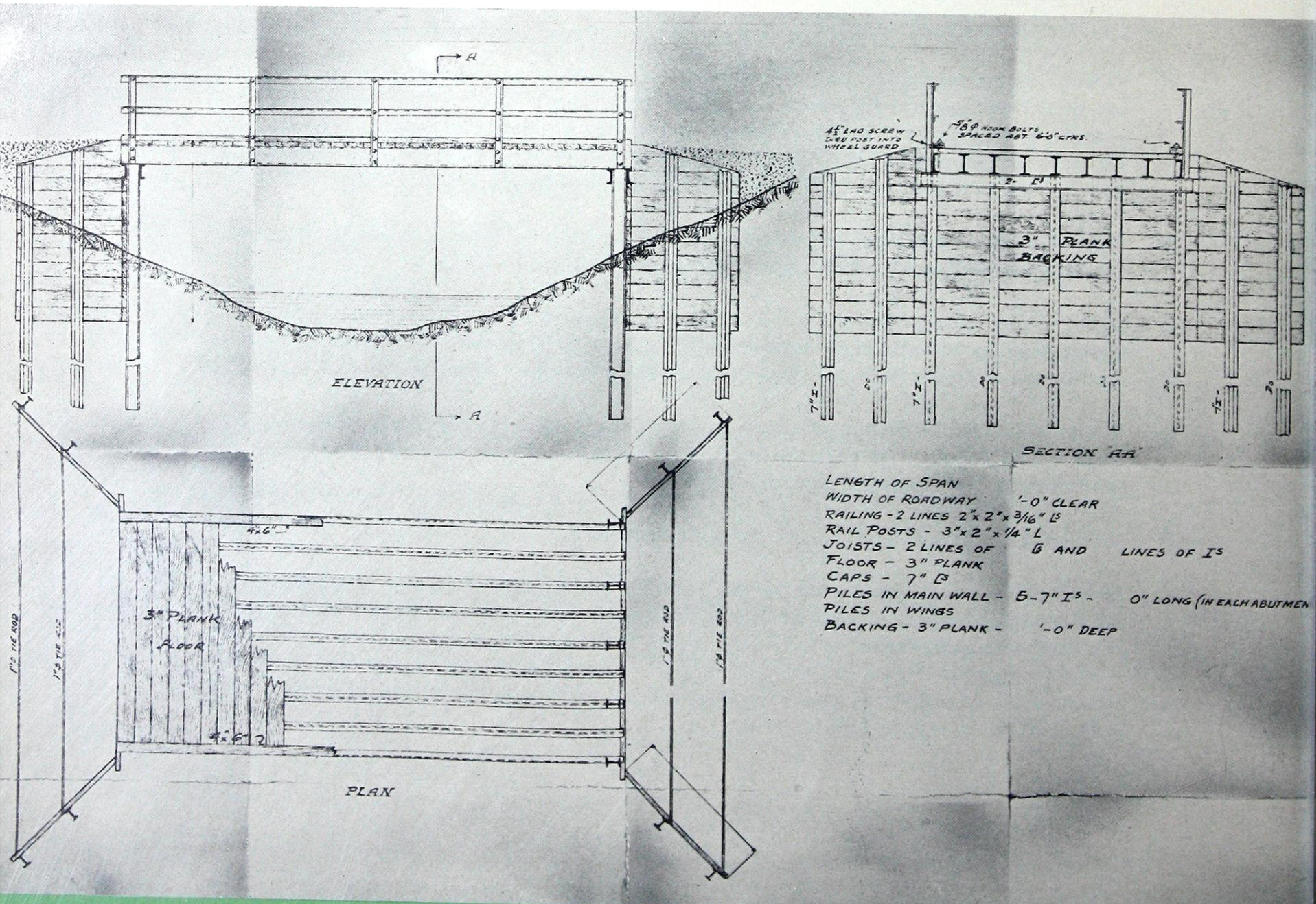
The illustrations are reproductions of two standard drawings used in the 90's. Note the blank spaces for inserting sizes of steel bearing piles; also method of retaining earth embankment fill back of planks supported by piles.

Many of these bridges were located on unimportant traffic arteries and were given very little attention and maintenance until recent years. Their widespread use, and the satisfactory performance of the steel piles supporting them received considerable publicity in the year 1932 when an article was published in *Civil Engineering* by J. G. Mason, State Bridge Engineer, and A. L. Ogle, Assistant Bridge Engineer, State Highway Department, Lincoln, Nebraska. The history of the use of steel piles for bridge construction in Nebraska parallels the same use in other adjoining States. The following typical remarks are quoted from the above mentioned article:

Early Types of Steel Pile Foundation:

"Examples of early steel pile construction can still be found in the eastern part of the State. These structures were of the type commonly called a 'bed-

Reproductions of 40 Year Old Drawings Showing



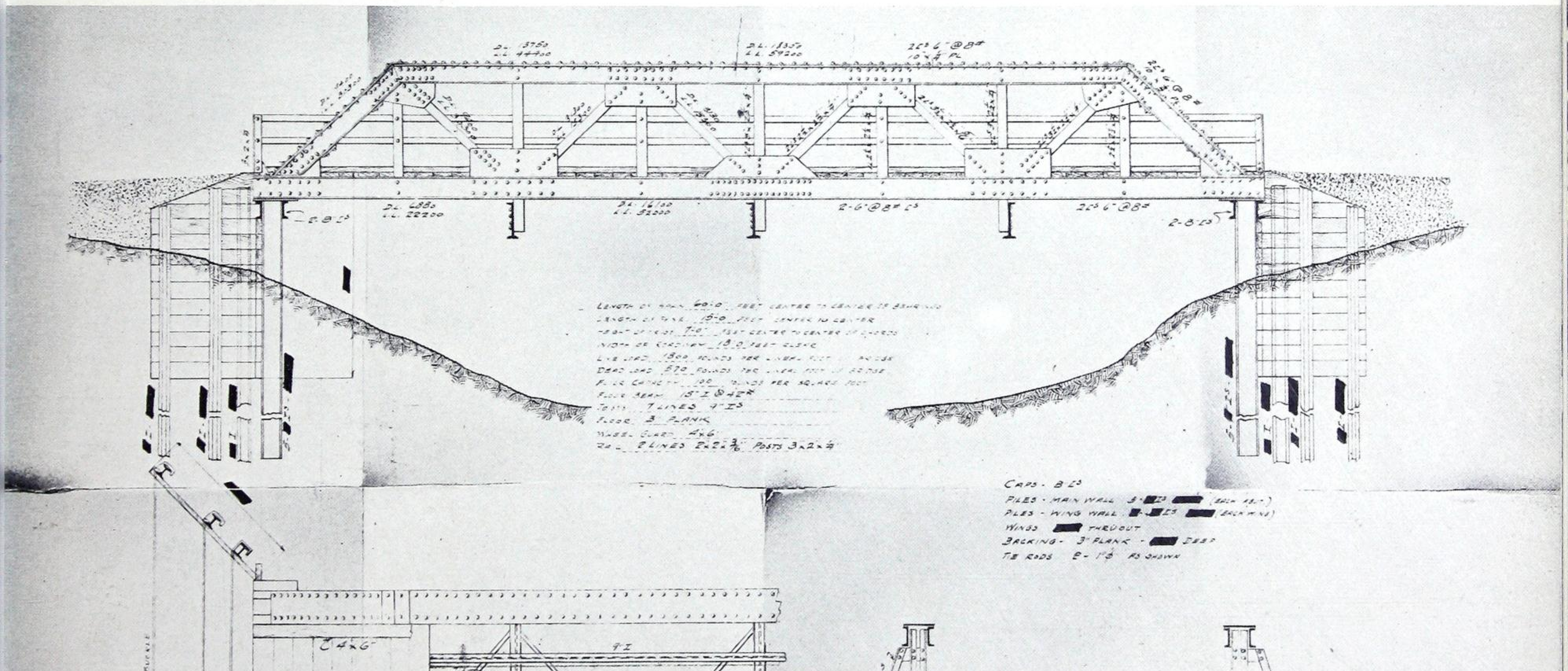
stead bridge.' Most of them were built in the late nineties and, therefore, are now from thirty to thirty-five years old. They are of light, pin-connected Warren type, or Pratt riveted pony truss design, rigidly fastened to steel columns, or legs, at each corner. The columns are built up with various combinations of channels, I-Beams, plates, and lacings, and founded on 12″ x 14″ oak sills laid in deep trenches.

"In 1901 and 1902, the use of simple I-Beam spans became more common. They were supported on 5″ and then on 8″ steel I-Beams driven as piles and capped with channels and plates. Wing piles were also employed, planks being bolted on to form the backs.

"In 1908, when wide-flange sections came on the market, smaller H sections were utilized for piling in place of the I-Beams. At this time, the deep, wide-flange beams and girder sections were used as new girder bridges, and were divided into panels by floor beams, spanned by steel stringers. Such I-Beam spans are still in use for the crossing of very narrow streams, but beginning in about 1919, the girder type just described gave way to the transverse joist girder type for spans between 35 and 60 feet. Simultaneously, H-Beam steel pile foundations were developed and used extensively by the various Boards and County Commissioners.

"In only very few of the old County bridges having steel pile foundations were the piles encased in concrete or protected in any way, except by coats of red lead paint. On a great many such piles examined, it was estimated that the decrease in section had not been more than 1% in twenty years. Exceptions were found in the Salt Creek Valley, which is saline to a marked degree. In that locality, several old steel

the Use of Steel Bearing Piles in the '90's.



bridges showed an estimated loss of section of about 2 or 2½%."

A series of steel trestle highway bridges were built about 1900 in the vicinity of Chatham, Ontario. Herewith are illustrations of these structures and we quote the following from an article by R. C. Manning in the July 7, 1931, issue of the *Canadian Engineer*.

"These trestles are supported on steel bearing piles made up of two channel sections riveted back to back which are driven into the bed of the waterway.

"A great many of these steel piles are driven so that they are in the water, and are subject to alternate wetting and drying action as the water level rises and falls. Judging from the fact that these structures are on county roads in out of the way places, it is fair to assume that little or no money has ever been spent on maintenance. The condition of the wood floors of some of these structures would also indicate a lack of attention.

"Seven structures of this general type were recently inspected by the writer, and the steel work was found to be in excellent condition. Although the surface of the steel is somewhat pitted, there is no evidence of serious corrosion. A wire brushing and a coat of

1

2

paint would put any one of these steel structures in first class condition. The steel piles are not corroded at the water line or in the area between the present water line and the high water mark which can be readily seen by the deposit of a light colored silt coating on the piles.

"These examples of long life of steel piles in fresh water are particularly interesting at this time when steel piles are being advocated for substructures of bridges and buildings."

An accurate determination of loss of section in steel bearing piles was made when the old St. Francis River Bridge at Lake City, Arkansas became obsolete due to lack of roadway capacity. It was dismantled in September, 1934. Following is the report by Dr. J. S. Unger, Manager, Central Research Bureau, Carnegie Steel Company, on the condition of the bearing piles.

"They were made up of 8" steel beams with 4" flanges. The estimated weight when new was 17.3 lbs. per foot. The bridge was completed during August, 1913.

"This pile was removed during August, 1934, after having been in service for twenty-one years. A piece

STEEL PILES INSTALLED, 1900

•

HIGHWAY BRIDGES
NEAR
CHATHAM, ONTARIO

•

1. NOTE EXCELLENT CONDITION OF STEEL PILES AS SHOWN BY CLOSE UP VIEW.

•

2 AND 3. NOTE RANGE OF ELEVATIONS OF WATER LEVEL AS INDICATED BY SILT DEPOSIT ON PILES.

•

4. VIEW SHOWING CONDITION OF STEEL PILES SUPPORTING PLANKING WHICH RETAINS EARTH FILL OF ABUTMENTS.

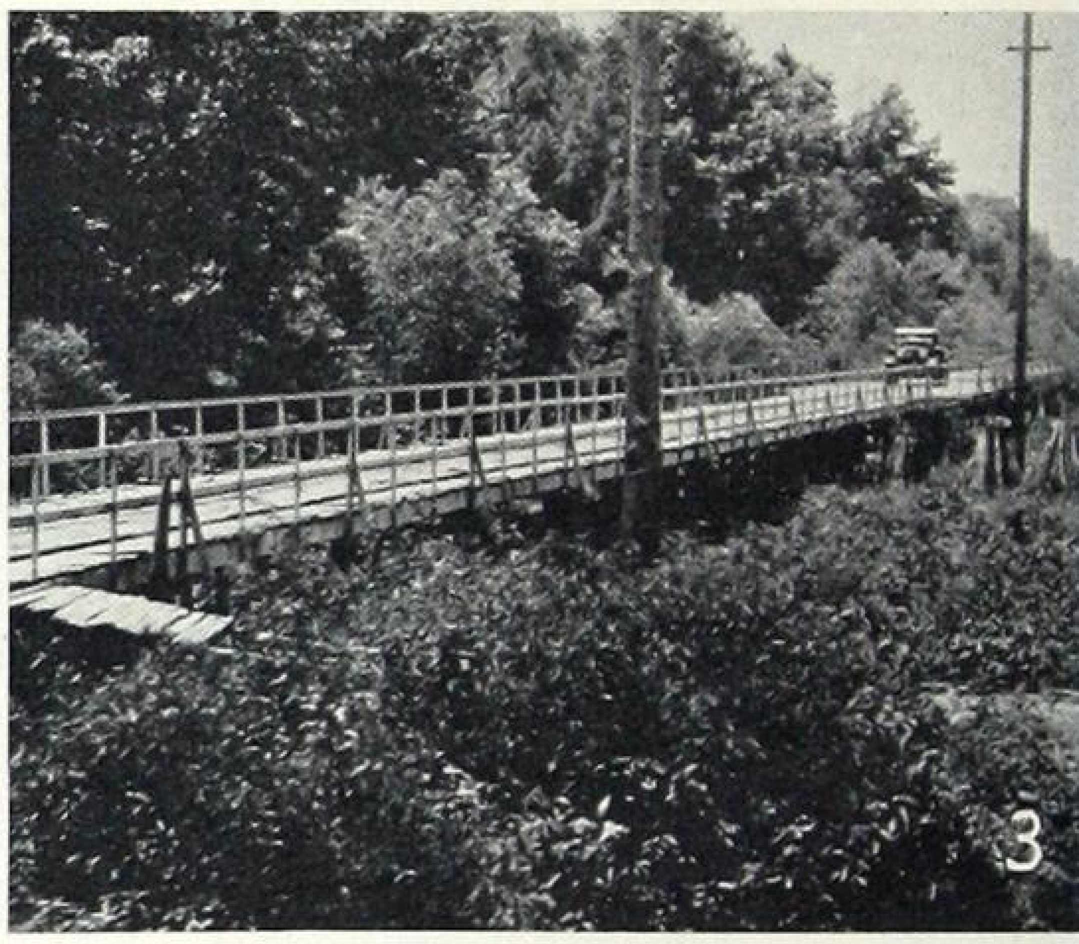
about one foot long was cut from the top of pile, and another piece of the same length from the ground level to one foot below. The top portion of pile had been protected to some extent by having been painted at least twice during the life. This was shown by the two colors of paint, some of which still adhered to pile. The bottom portion, or that at the water level, did not show any evidence that it had ever been painted since installation.

"Lake St. Francis is a part of the ancient Mississippi River channel. Lake City is located in Craighead County, Arkansas, at the southern end of Lake St. Francis, about 50 miles northwest of Memphis, Tennessee. The soil is an easily drained sandy loam. The water of the Lake has a neutral reaction and contains about the same salts found in the Mississippi River.

"The State Highway Department of Arkansas decided to remove this old structure during September, 1934, and replace it with a new larger bridge.

Kind of Steel and Loss of Metal:

The following chemical analysis was made from one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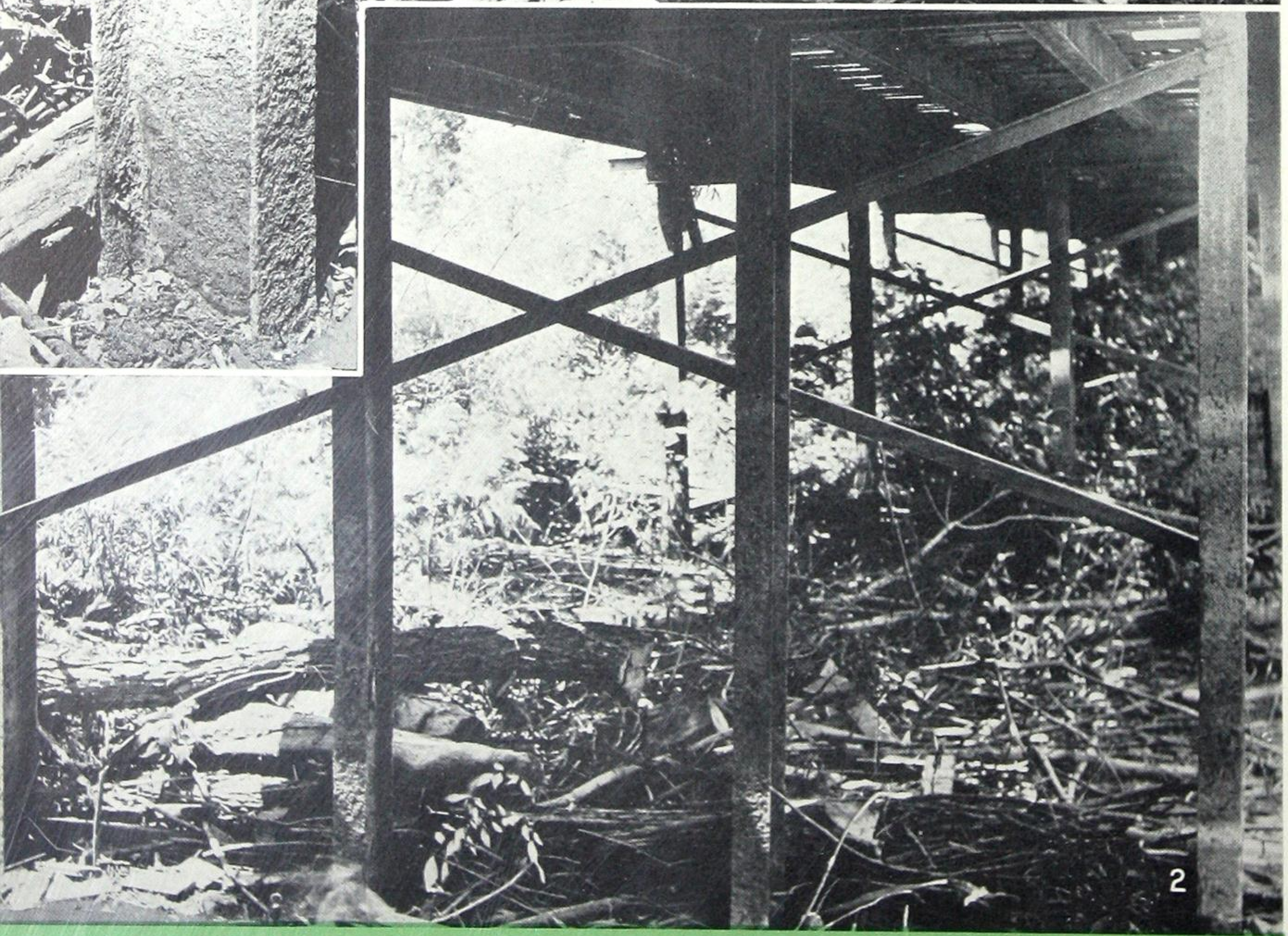
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STEEL PILES INSTALLED, 1913

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ST. FRANCIS RIVER BRIDGE, LAKE CITY, ARKANSAS

•

1. CLOSE UP SHOWING CONDITION OF PILES AT GROUND LINE. NOTE COATING OF SILT AND LOOSE SCALE. NOTWITHSTANDING ROUGH APPEARANCE, THE STEEL WAS IN GOOD SHAPE, AS NOTED IN REPORT ABOVE.

•

2 DETAIL VIEW OF TYPICAL TRESTLE BENTS. NOTE ANGLE CROSS-BRACING AND DOUBLE CHANNEL CAPS BOLTED TO STEEL PILES.

•

3 AND 4. GENERAL VIEWS SHOWING CHARACTER OF TERRAIN.

•

5. VIEW OF WEB AND FLANGE FROM TOP END OF PILE SHOWS FOUR ORIGINAL BOLT HOLES.

•

6. HOLES APPEARING IN SECTION AT WATER LINE WERE DRILLED TO OBTAIN CHIPS FOR ANALYSIS OF STEEL.

•

NOTE RELATIVELY SMOOTH NEW APPEARANCE OF TOP SECTION AND ABSENCE OF LARGE PITS IN SECTION REMOVED AT WATER LINE.

of the short pieces:

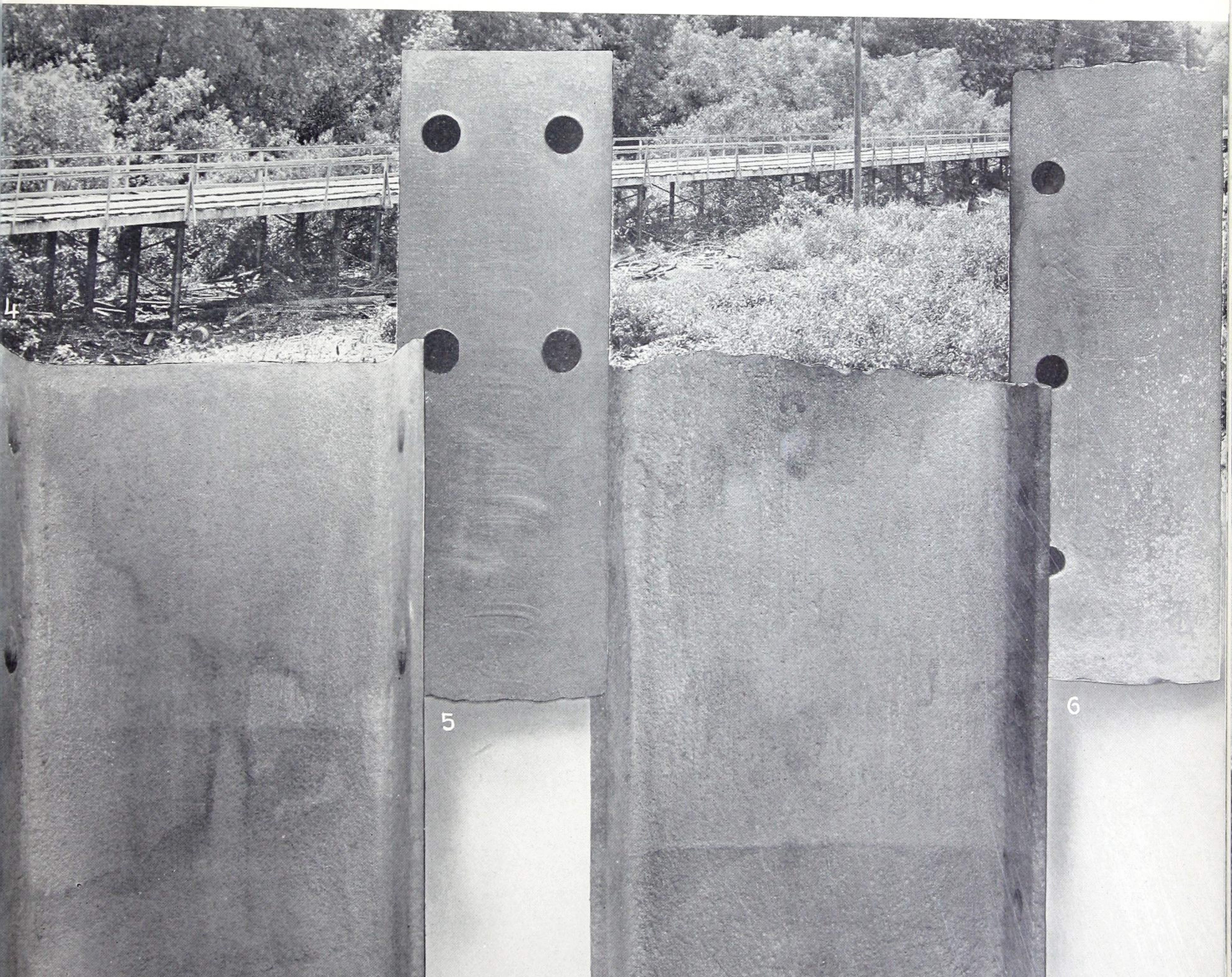
Carbon	.29 per cent
Manganese	.49 per cent
Phosphorus	.016 per cent
Sulphur	.034 per cent
Silicon	.019 per cent
Copper	.010 per cent

which shows it is ordinary non-copper bearing open-hearth steel.

"Careful calipering and examination showed the original estimated weight was 17.3 lbs. per foot.

"After a slight pickling to remove the dirt, paint and scale, the specimens weighed 16.6 lbs. per foot. This shows a loss in weight of only .70 lbs., or 4.0%, after twenty-one years' service.

"The top portion of pile was free from pitting, while the bottom portion, or that at the ground level, had a few shallow pits but not of sufficient volume to make any perceptible difference in the weights of the respective specimens. The appearance of the surface of the pile (see photographs), and the slight loss in cross section at the zone of worst corrosion—4.0%

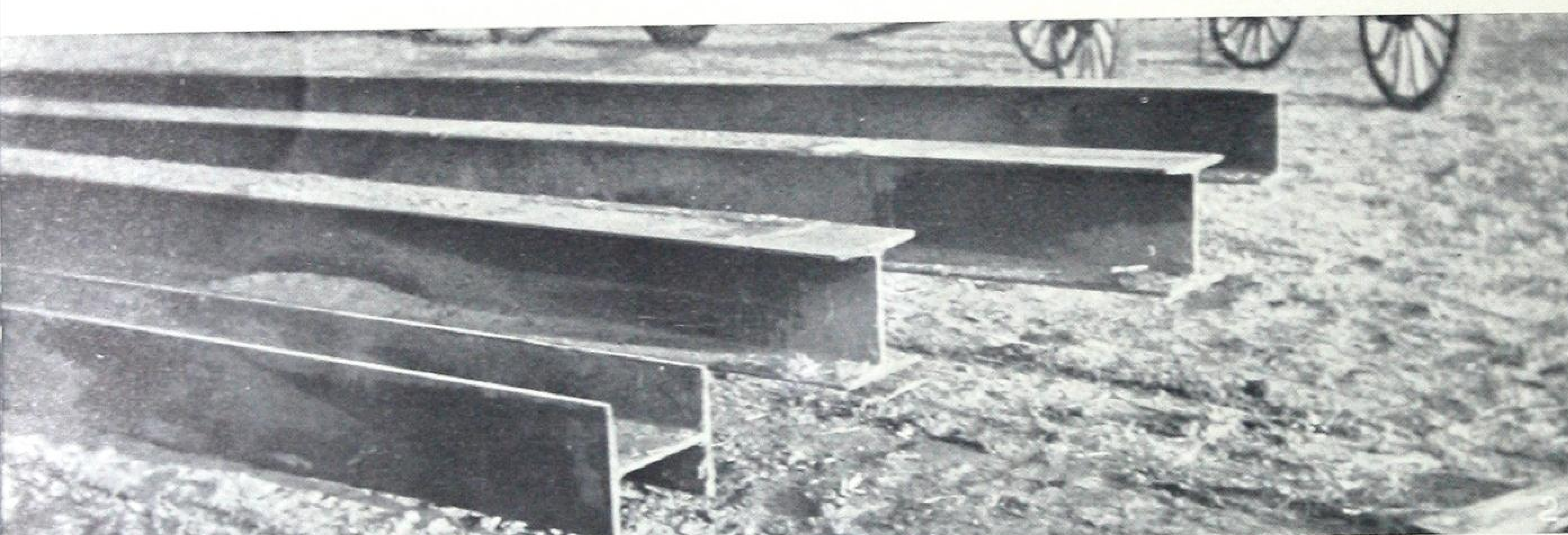


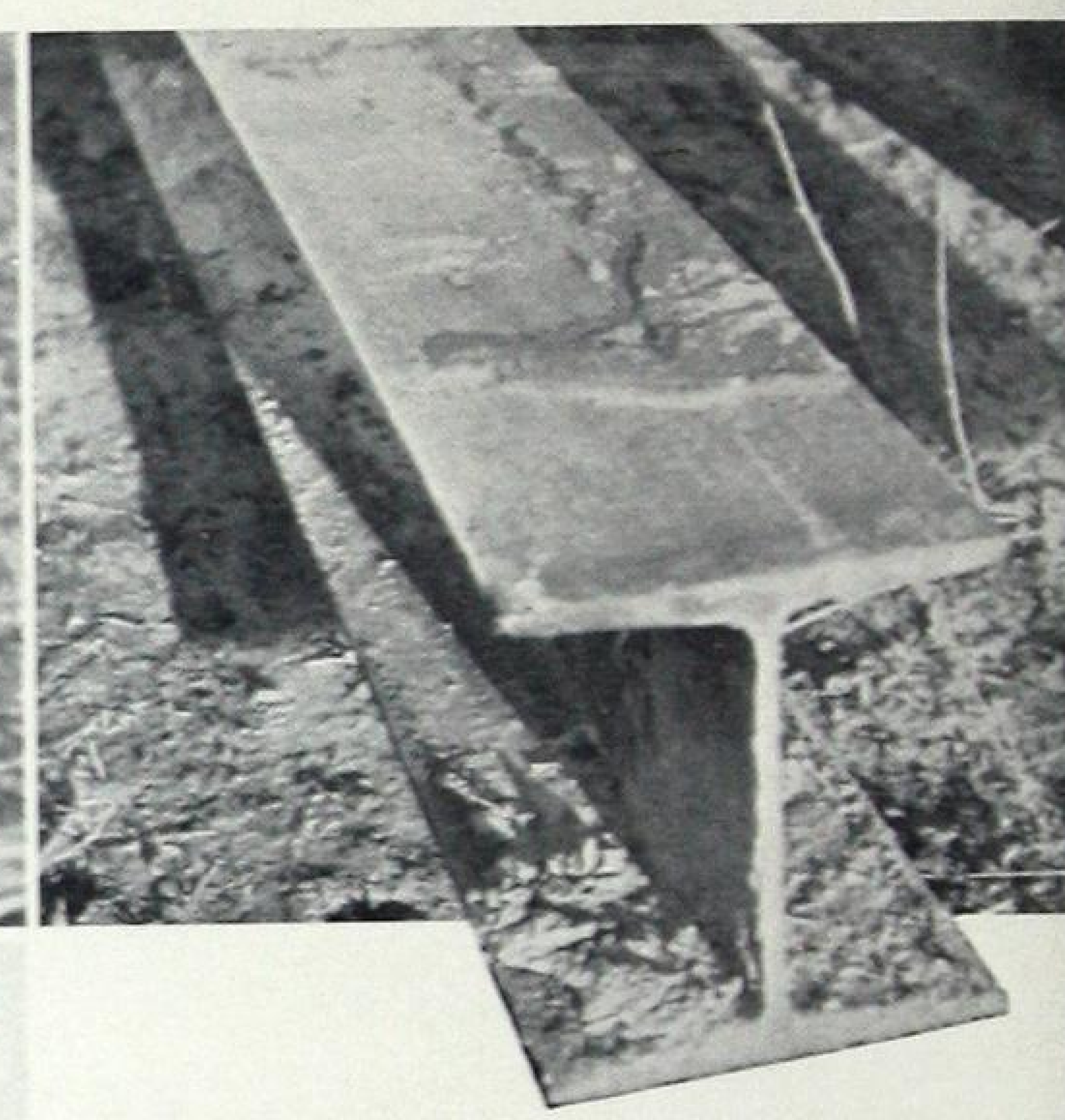
after twenty-one years' service—indicate that bearing piles under like conditions would have an actual, effective, safe life of between 50 and 100 years."

Steel piles driven in 1912 and withdrawn twenty-two years later were not only found to be in good condition, but will be used again for new work as per letter by J. G. Mason, Bridge Engineer, Bureau of Roads and Bridges, State of Nebraska:

"Enclosed are photo prints of the Columbus Platte River Bridge which was abandoned a year or two ago on account of obsolescence as to capacity and roadway width. On two of the close-up views of the old pulled piles, you will note the appearance of a scale or crust which resembles a stucco finished house of the pebble dash type. I believe I showed you samples of this scale which consists of natural gravel cemented with sandy mortar of a rusty red color. It is our opinion that this "mortar" is cemented by the oxidation of the original mill scale, since the crust may readily be scraped off, exposing a true plane surface of steel, unpitted.

"For your further information, the upper 8 feet of the pile which was in the air, was but slightly pitted in an amount much less than that shown on the super-





STEEL PILES INSTALLED, 1911 WITHDRAWN FOR RE-USE IN OTHER WORK.

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PLATTE RIVER BRIDGE, SOUTH OF COLUMBUS, NEBRASKA

•

1. GENERAL VIEW OF BRIDGE. NOTE CROSS-BRACED TRESTLE BENT OF ONLY FOUR STEEL PILES SUPPORTING ENDS OF TWO TRUSS SPANS.

•

2. NOTE GOOD CONDITION OF PILES AFTER PULLING.

•

3. EQUIPMENT USED IN PULLING PILES.

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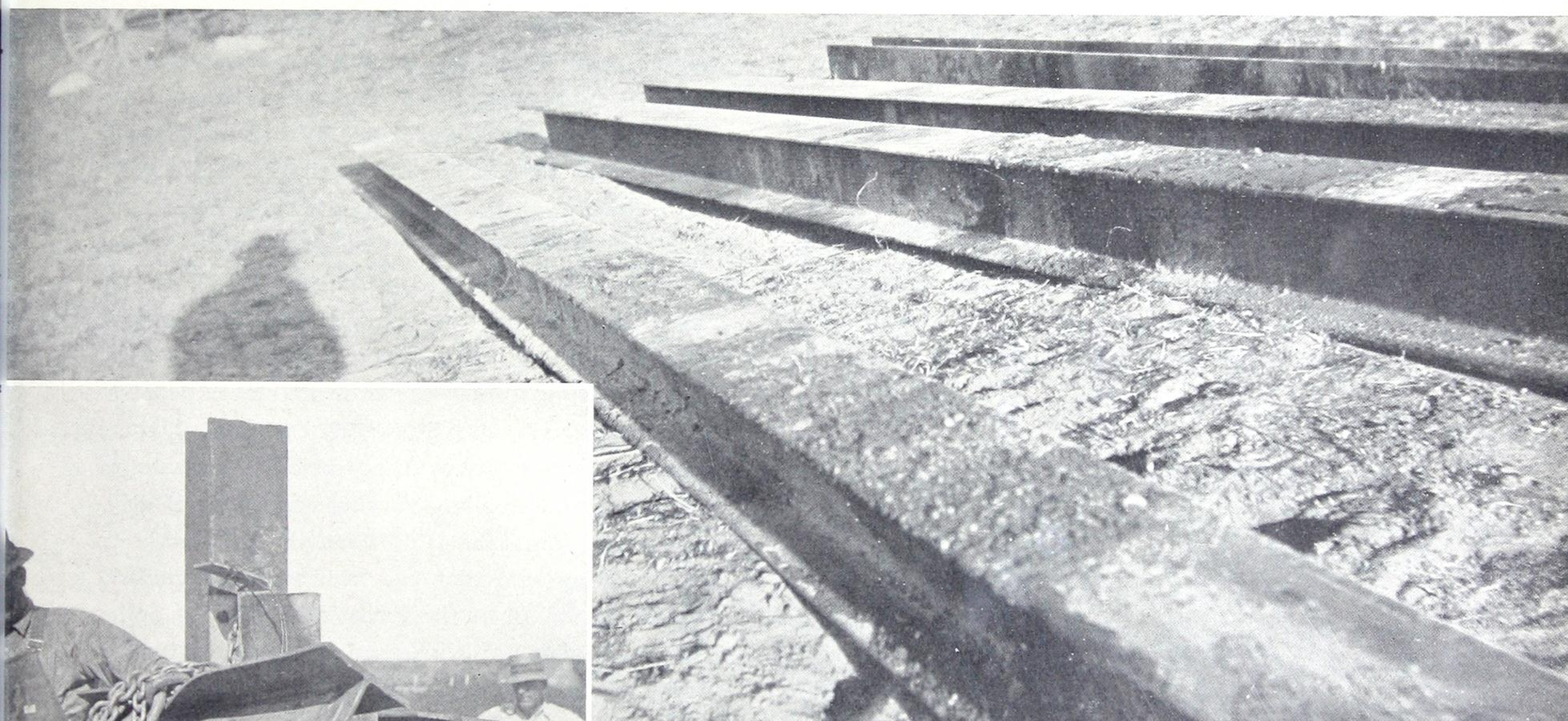
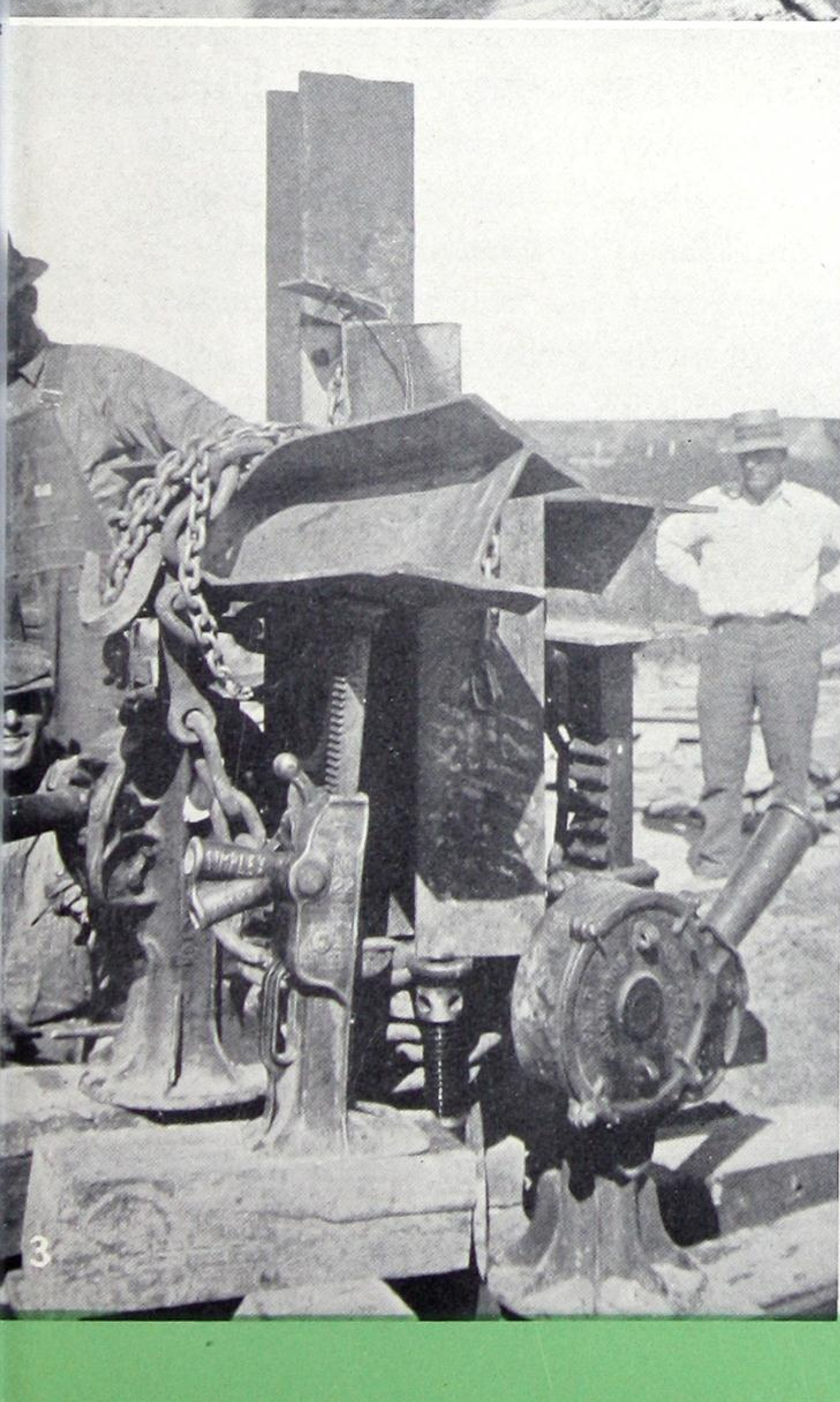
OTHER VIEWS SHOW STUCCO-LIKE COATING OF CEMENTED SAND AND GRAVEL ADHERING TO PILES AFTER PULLING.

structural steel. This medium condition is due no doubt to the vertical position of the exposed surfaces of the piles. At the ground line, and perhaps two feet above and two feet below, a greater amount of pitting was found, but at the most severely attacked section I would not estimate a greater reduction in thickness between pits on opposite surfaces than one-sixteenth of an inch.

"I understand that these piles are to be used by the county for other bridge work and that they will be turned end for end so that the slightly damaged end will be driven far below flow line. It is reasonable to suppose that being thus buried and insulated from exposure to the air, the corrosive action will be suspended or completely checked for an indeterminate period—certainly for 80 to 100 years or more. Meanwhile, by properly encasing the pile at ground line, the whole unit may be made to last as long as the buried section.

"I have heard a theory expounded that the encrustation described above might in reality act as a protective coat from any further corrosion. After having seen these examples, I am personally inclined to give more credence to the theory."





CHARACTERISTICS OF "CBP" BEARING PILES

Bearing Capacity and Driving Formulas:

Experiences gained through the use of wide flange CB sections as rolled steel bearing piles indicate conclusively that their action in driving, and the resultant sustaining or bearing values are developed in a manner which is different from the action and results obtained from piles of other shapes and materials.

With respect to their bearing capacity, piles may be roughly divided into two classes:

•

I. *Those which are driven to refusal into very hard or dense material, such as rock, shale, cemented sand and gravel, and hardpan—that is, very firmly compacted gravel or clay.*

A pile whose point is embedded in material of this class when driven through a soil that is sufficiently firm to brace the pile throughout its full height against lateral movement, may be computed to sustain a load equal to the safe resistance to crushing on the least assumed effective cross section. If the surrounding soil is lacking in stability and yields readily, the bearing power of the pile is its safe load computed as a column, having an unsupported length equal to the total length of pile. Between firm, and plastic or yielding soils, there are varying degrees of lateral support to be considered and the engineer must use discretion and judgment in evaluating these characteristics. When CBP sections are used under this classification, it will be found that they can be driven into cemented sand or gravel and soft rock from 10 to 15 feet, into hard shale from 1½ to 8 feet, and into hard rock sufficiently to secure good seating. Where the piles rest on hard rock, it may be desirable to increase the cross sectional area of the point as discussed elsewhere in this booklet.

II. *Those which do not reach dense, hard strata of sufficient thickness to develop full resistance to penetration in a very short length of pile point.*

The pile belonging to this division depends for its sustaining power upon the friction, shear value, cohesion, and to a slight extent on the buoyancy of the soil into which it is driven. The safe loads for such piles may be determined by the average penetration of the pile under the last four or five blows of the hammer. It is usually stipulated that the penetration under a given type of hammer shall not exceed more than a given number of blows per inch averaged over the last three inches of penetration. Reliable values for a given site and total length of pile, as well as final penetration, can only be computed by first driving test piles and determining their actual capacities by means of loading tests. While the amount of penetration of a steel pile may be exactly determined, there are so many conditions that modify the rate of penetration and so many varying conditions of driving, and of soil, that it is virtually impossible to formulate any rule that can be considered entirely satisfactory for all of the essential conditions under which such piles are driven unless, as stated before, the formulae are checked through actual load tests. This is also true with respect to any type of pile made of any kind of material.

Based on driving and test information, now available, for determining the approximate sustaining value of a pile for very hard driving, the modified Wellington or Engineering News-Record formulae as given on next page with $F=2$ may be used; for relatively easy driving higher values of F should be used as given. The reason for using variations in F values is that very hard driving indicates that the major factor in building up sustaining value is point resistance, whereas relatively easy driving indicates that the major factor is side friction.

For piles driven with drop hammers, $P = \frac{FWh}{S+1}$

For piles driven with single-acting steam hammers, $P = \frac{FWh}{S+0.1}$

For piles driven with double-acting steam hammers, $P = \frac{Fh\,(W+ap)}{S+0.1}$

F = 2, for piles driven to refusal or practical refusal in all materials.

For piles which drive easily, use values of F as follows:

- F = 6, for piles driven in sands and/or gravels,
- F = 4, for piles driven in hard or sandy clays,
- F = 3, for piles driven in mixed medium clays and sand or sand and silt,
- F = 2, for piles driven in alluvial deposits, soft clays and silts.

P = safe load in pounds,

S = penetration in inches under the last blow or the average under the last five blows,

W = weight of hammer or ram in pounds,

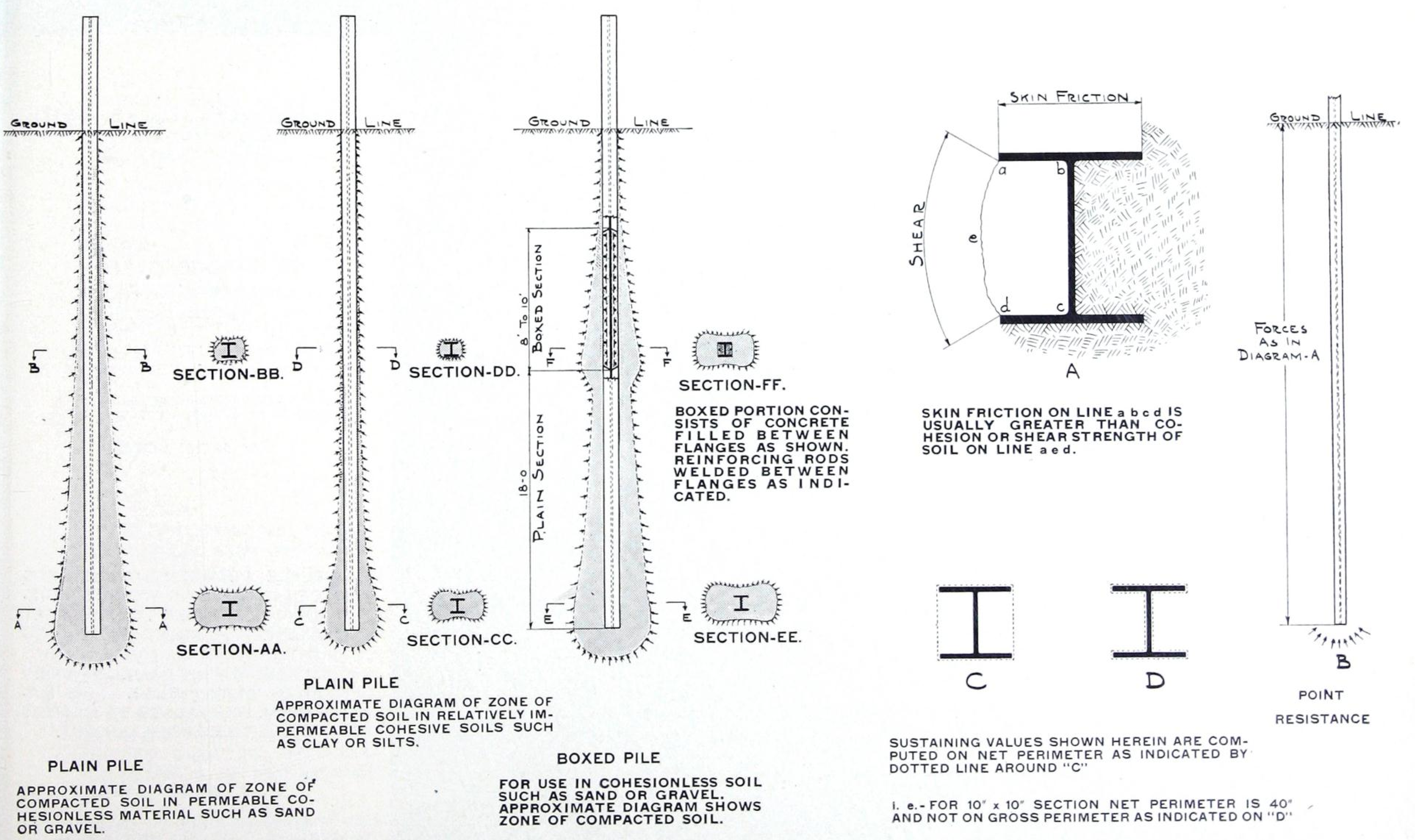
a = effective area of piston in sq. in.

p = mean effective pressure of steam or air in pounds per sq. in.

h = fall of hammer or stroke of piston in feet.

The value of the penetrations, or sinking of the pile, under the last five blows should be used only if the pile has shown a fairly uniform or rational increase in resistance to driving as the total depth of penetration of pile increases.

The safe loads derived from the above formulae are based on a safety factor of approximately 2. This is in accordance with current practice, as most engineers specify load tests ranging from 1½ to 2 times the design loads. Most tests on rolled section steel bearing piles show close agreement with the formulae, while others are at considerable variance. The values obtained by the formulae are generally conservative and on the side of safety.



DIAGRAMS OF SUPPORTING FORCES ON ROLLED STEEL CBP SECTION BEARING PILES

Where piers or footings, supported by piles, also rest on the soil into which the piles are driven, the factor of safety is increased appreciably due to the sustaining value of the soil under the footing area.

Referring to diagrams on page 17, it will be noted that a class II steel bearing pile of H or I section builds up its load-carrying capacity partly by skin friction of the outer surfaces of the section; partly by shear on the line between the outer edges of the flanges; and partly by point resistance.

Throughout this booklet we are using the term "sustaining value" when evaluating the carrying capacity of piles which are dependent on the above factors, that is, piles whose points are not driven to refusal in a very hard-resisting strata of soil.

Driving Phenomena:

When a steel CB section is driven, the soil is compacted so tightly in the troughs between the flanges and the web that its frictional value against the steel

STEEL PILES PULLED FROM OLD WING WALLS

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BRIDGE OVER LODGEPOLE CREEK, NEBRASKA

•

8″ H 20′ LONG

•

SPACE BETWEEN LOWER ENDS OF FLANGES AND WEBS FOR DISTANCE OF THREE TO FOUR FEET ABOVE PILE POINT WAS FILLED WITH NIOBRARA CHALK (SOFT SHALE) WHICH CAME UP WHEN PILES WERE PULLED. THIS MATERIAL WAS PACKED SO TIGHTLY IT HAD TO BE CHISELED OUT.

•

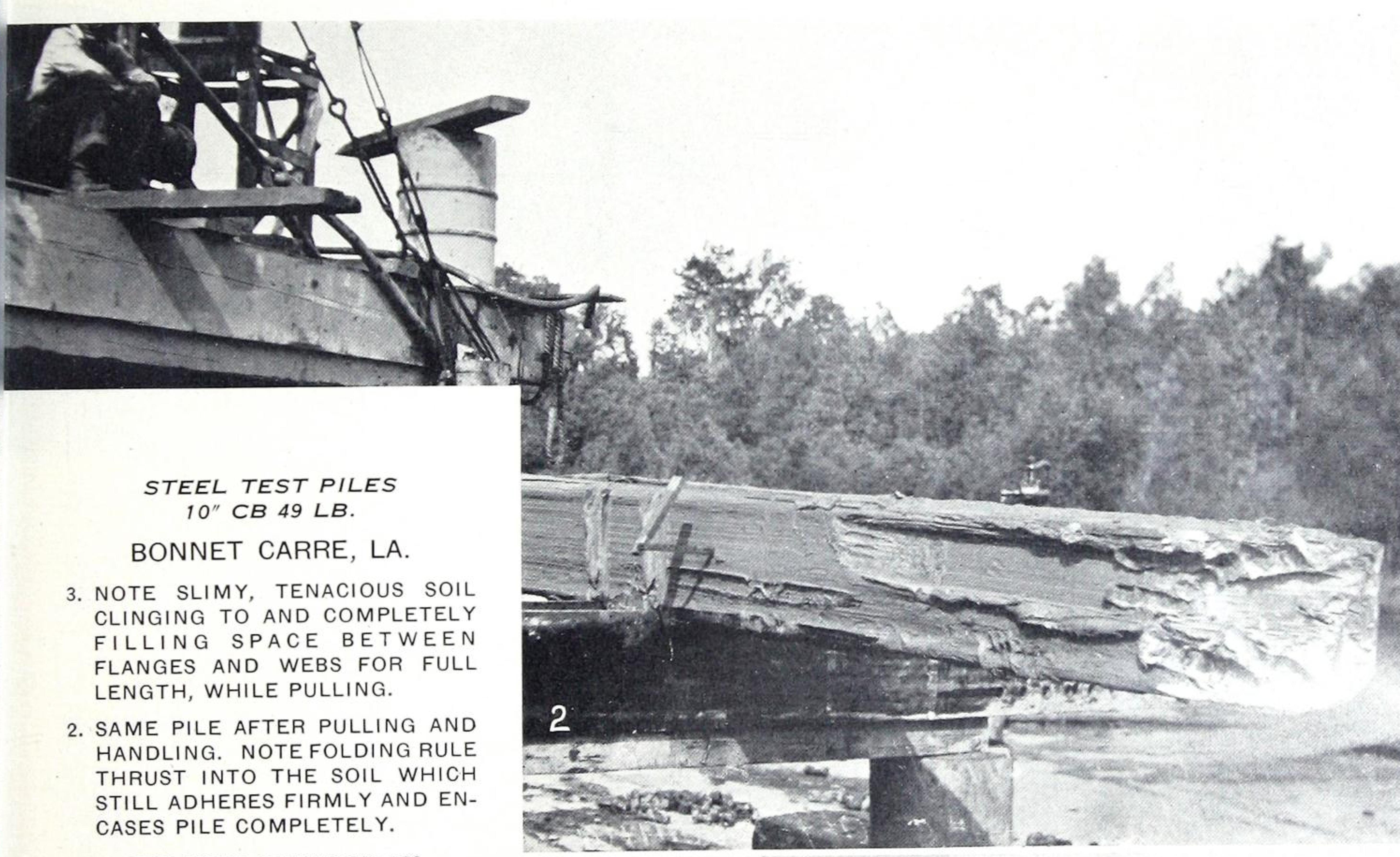
PHOTO THROUGH COURTESY OF J. G. MASON, BRIDGE ENGINEER, STATE OF NEBRASKA

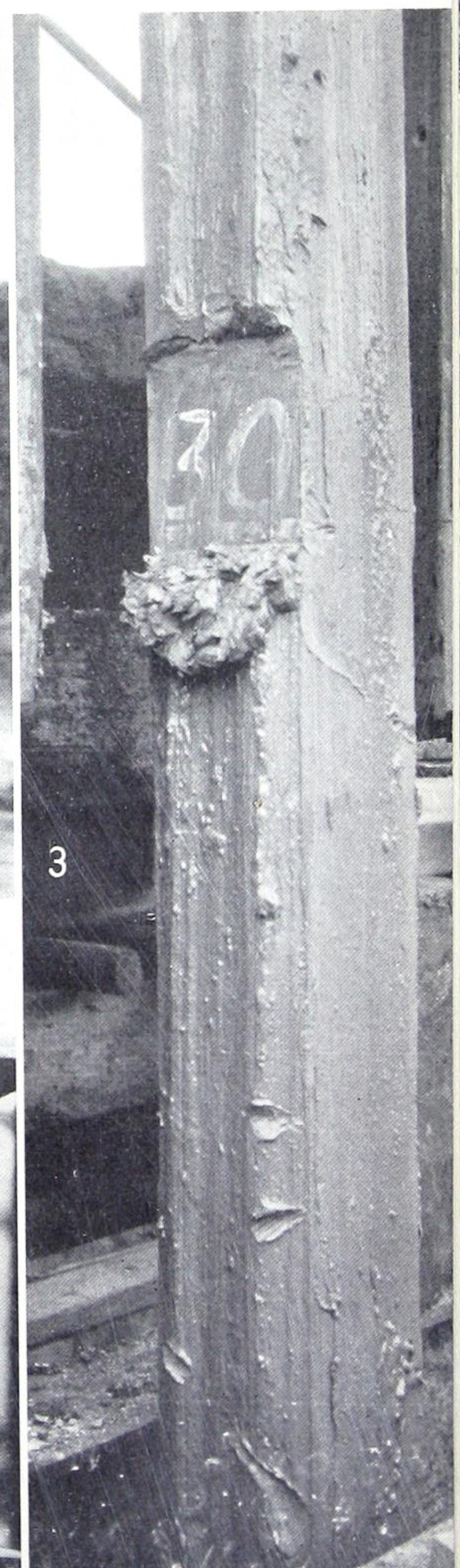
is greater than the shear or cohesion value of the soil on a plane between the toes of the flanges, hence the compacted soil is dragged down with the pile as penetration continues and gradually forms a considerable bulb of pressure near the lower end as illustrated in diagram on page 17.

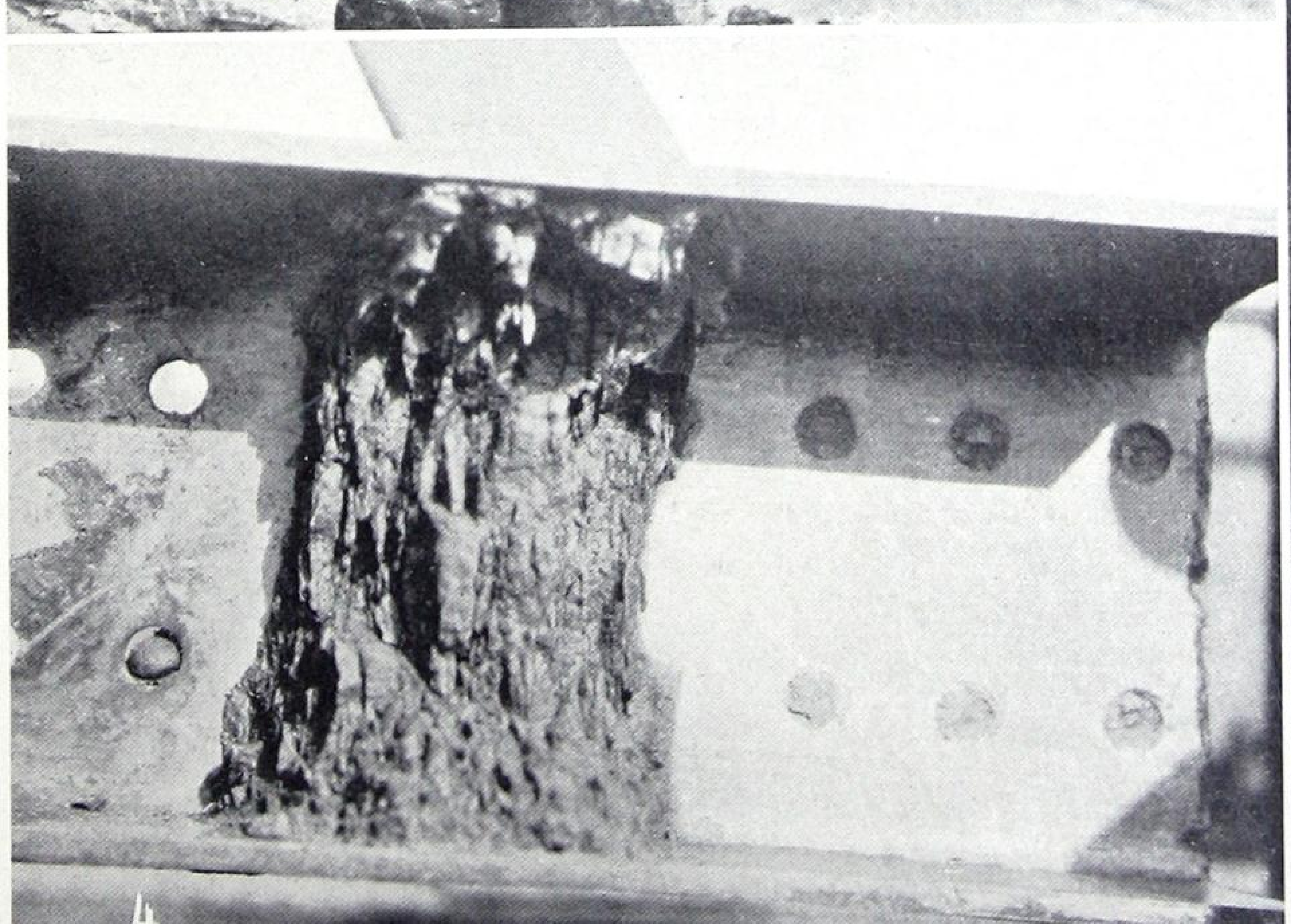
When piles are considered as long columns, it should be borne in mind that a steel section will usually be comparatively straight and true. It is, therefore, not subjected to stresses and deformation due to eccentric loading to so great an extent as would a crooked pile, or one which is easily deflected during driving.

Steel piles cause less rupture and shifting in the soil than is the case with displacement piles. This means less effect on adjacent structures, greater ultimate carrying capacity for a given area of footing, and less movement or rebound after driving.

Once driven, steel piles remain firmly set in the earth and show little tendency to heave up during the driving of adjacent piles.







STEEL TEST PILES
10" CB 49 LB.

BONNET CARRE, LA.

3. NOTE SLIMY, TENACIOUS SOIL CLINGING TO AND COMPLETELY FILLING SPACE BETWEEN FLANGES AND WEBS FOR FULL LENGTH, WHILE PULLING.
2. SAME PILE AFTER PULLING AND HANDLING. NOTE FOLDING RULE THRUST INTO THE SOIL WHICH STILL ADHERES FIRMLY AND ENCASES PILE COMPLETELY.

PILE TESTS CONDUCTED BY AMERICAN BRIDGE COMPANY

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STEEL FALSEWORK PILE
12" H 65 LB. FOR BRIDGE

MILFORD TO BLACK EDDY
N. J. PA.

4. SHALE ADHERED BETWEEN FLANGES OF PILE FOR SIX TO EIGHT FEET ABOVE POINT. WORKMEN BEGAN TO REMOVE IT WITH PICKS. PROGRESS WAS SO SLOW THAT PILES WERE SHIPPED BACK TO THE SHOP FOR REMOVAL OF THE BALANCE WITH AIR TOOLS.

DESIGNED BY JOINT COMMISSION FOR ELIMINATION OF TOLL BRIDGES BETWEEN NEW JERSEY AND PENNSYLVANIA, TRENTON, N. J.

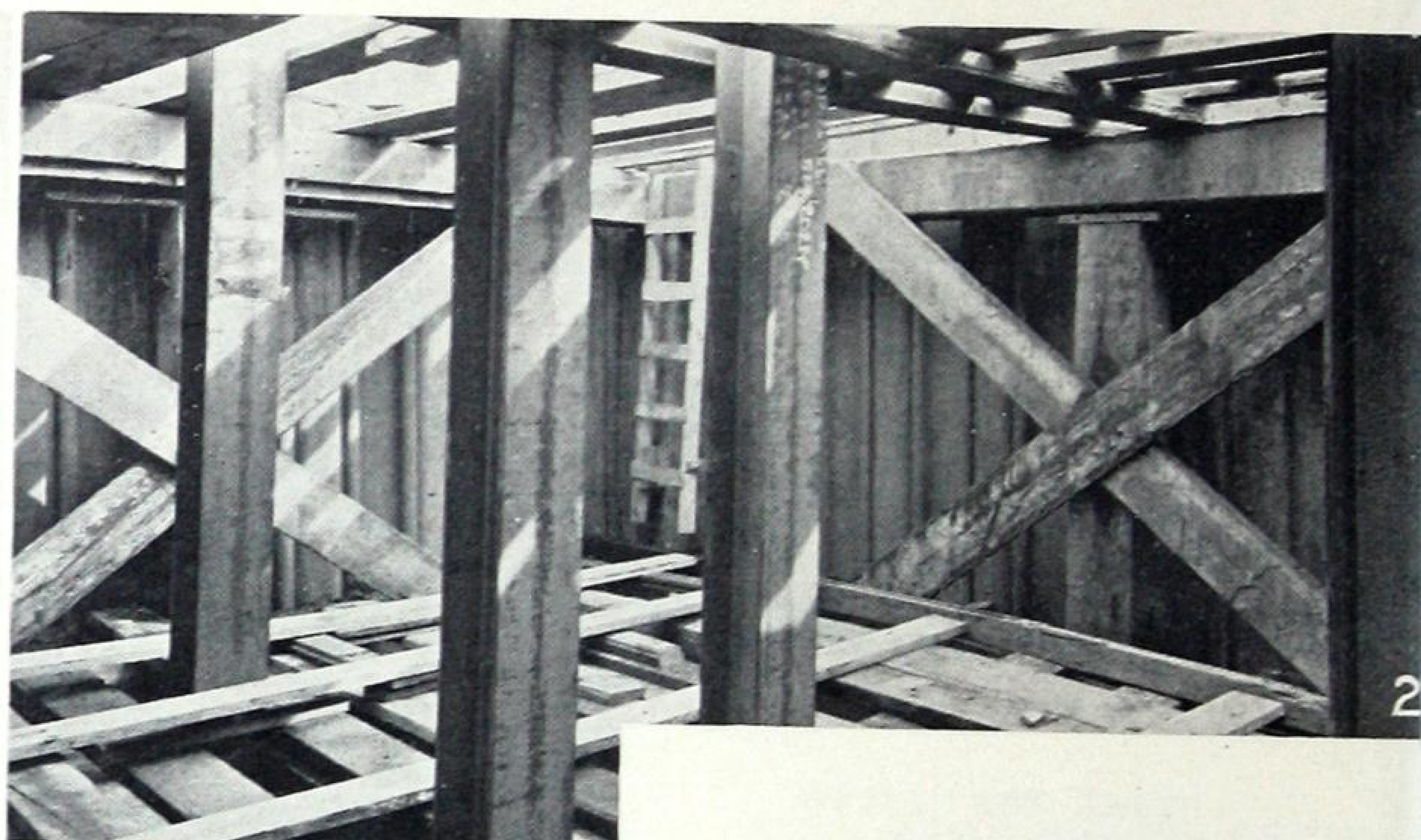
FABRICATED AND ERECTED BY McCLINTIC-MARSHALL CORPORATION

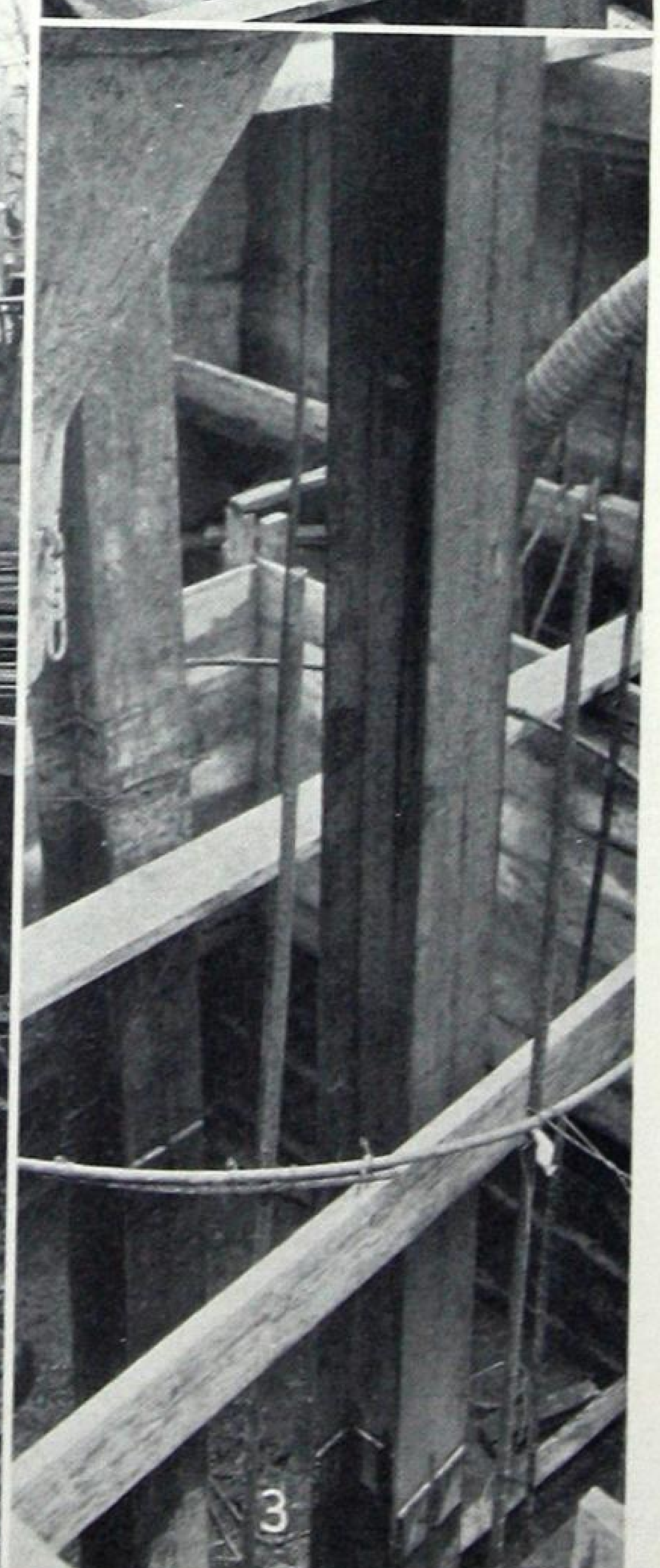
Steel piles are not easily damaged by over-driving, although there may be occasional battering or upsetting at the top. Even in extreme cases there may be considerable deformation at the top with no damage to any intermediate portion, thus assuring the engineer of no loss in capacity due to severe driving.

It is not necessary to jet steel piles to obtain any required penetration.

A steel pile can be driven through strata where no penetration can be secured with piles made of other materials. This permits the introduction of an added safeguard, as it is possible to drive one pile of a group an additional eight or ten feet to probe the depth of the hard stratum and prove its capacity beyond any doubt.

There is considerable difference in the penetrability of various soils. Steel piles penetrate with greater apparent ease than other types and for this reason, in many instances, under load tests they have developed safe loads much greater than would be





MERAMEC RIVER BRIDGE
ROUTE 61, 10 MILES SOUTH OF
ST. LOUIS, MISSOURI

•

APPROXIMATELY 500 TONS OR 20,000 LINEAL FEET REQUIRED FOR 457 INDIVIDUAL PILES OF 10" CB 49 LB. SECTIONS. FURNISHED IN 40' AND 60' LENGTHS. SPLICED BY WELDING IN FIELD TO THE LENGTHS REQUIRED AND DRIVEN TO ROCK, WHICH IS A HARD DOLOMITE. AFTER REACHING ROCK, PILES WERE GIVEN 500 BLOWS WITH HAMMER PREPARATORY TO FINAL REFUSAL CHECK WHICH CONSISTED OF AN ADDITIONAL 100 BLOWS. PILES WERE ACCEPTED IF THEY DID NOT PENETRATE MORE THAN 1" UNDER THE FINAL 100 BLOWS.

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1. PILES ERECTED AND PARTIALLY DRIVEN IN STEEL SHEET PILING COFFERDAM.

•

2. STEEL BEARING PILES ENTERED IN COMBINED GUIDE FRAMES AND COFFERDAM BRACING.

•

3. FORM WORK IN PLACE FOR UPPER PART OF PIER SHOWING TWO OF THE STEEL PILES EXTENDING CONTINUOUSLY UP INTO IT.

indicated by the conventional formulae. They can be driven through buried timbers or cribbing which would absolutely stop other forms of piling. Sufficient penetration can be secured in cemented sand and gravel to permit the development of full column loads on the section. Reasonable penetration can also be secured in glacial till and even in boulder strewn material, where the impact of the steel will crack and break up small stones and boulders.

When driving to rock, the relatively soft overlying strata can usually be penetrated to a depth great enough to insure bearing over the entire end of the steel section.

While certain pile driving formulae are referred to herein for approximate results, it is hoped that an increased and extended use of steel bearing piles will result in the accumulation of data which will permit the derivation of more rational formulae which will give reasonably accurate results with steel bearing piles.

MERAMEC RIVER BRIDGE
ROUTE 61, 10 MILES SOUTH OF
ST. LOUIS, MISSOURI

•

4. STOCK PILE OF 40′ AND 60′ LENGTHS OF PILES. NOTE PORTABLE CRANE LIFTING A LENGTH OF BEARING PILE.

•

5. BEARING PILE CAPS CUT FROM CB SECTIONS.

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6. DETAIL OF WELDED FIELD SPLICE.

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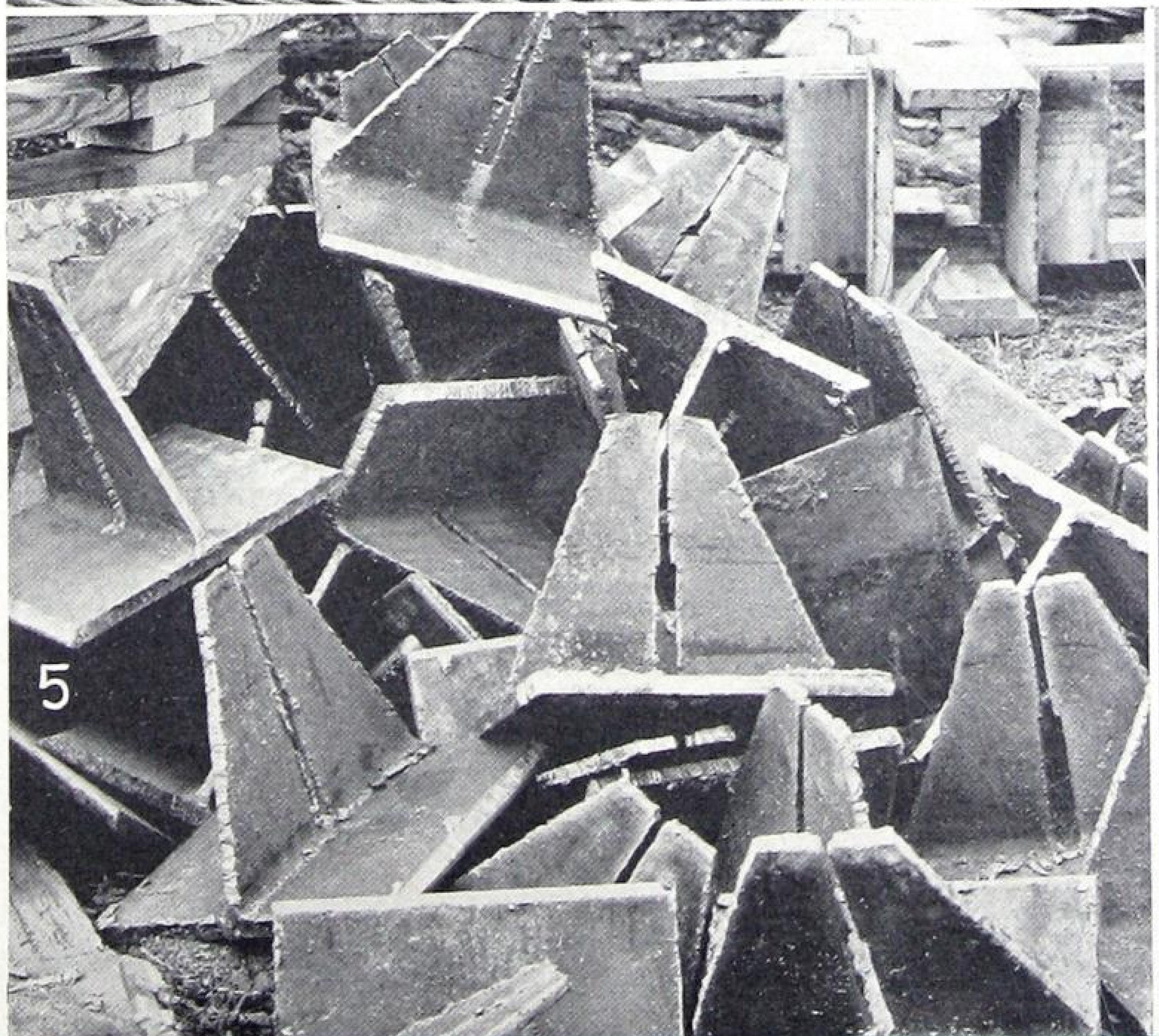
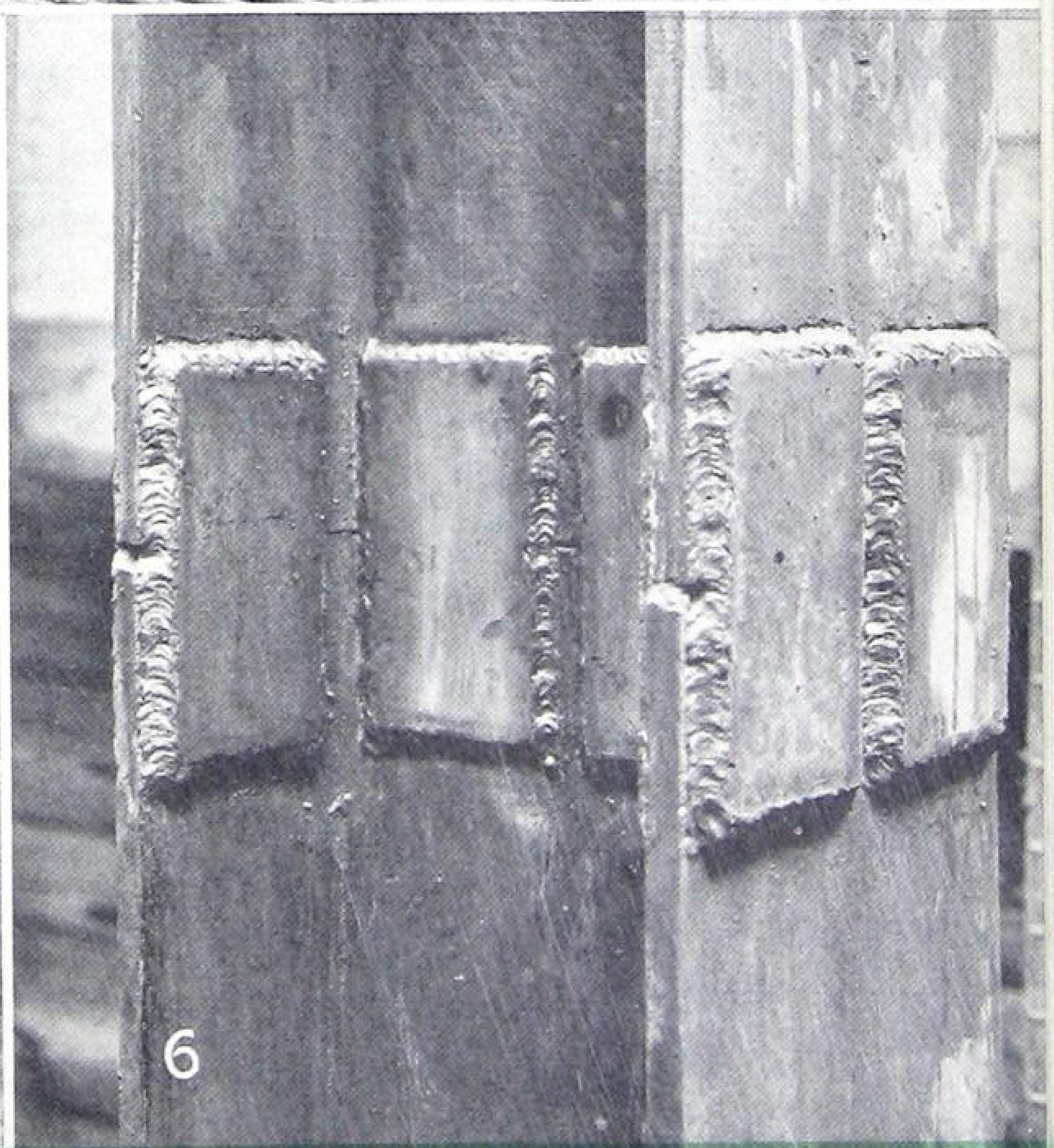
DESIGNED BY
MISSOURI STATE HIGHWAY COMMISSION
N. R. SACK, BRIDGE ENGINEER
SAMUEL KRAUS COMPANY, ST. LOUIS, GENERAL CONTRACTOR
STUPP BROTHERS BRIDGE & IRON COMPANY, ST. LOUIS, STRUCTURAL STEEL FABRICATOR





ENGINEERING AND DESIGN

A number of typical structures supported by steel bearing piles are illustrated in this booklet. An attempt has been made to select a wide variety of representative types of construction. In nearly all cases, there are both line drawings of essential details, as well as actual photographs of the completed structures. The following remarks and comments on design are intended as a guide in procedure and they should be employed in the light of and in conjunction with experience, judgment, and mature engineering knowledge.

Selection of Suitable Sections:

CBP sections, especially developed for use as bearing piles, are shown in the table on page 47. In addition to these special sections, any of the other wide flange CB sections may be used where the designing engineer finds they are applicable.

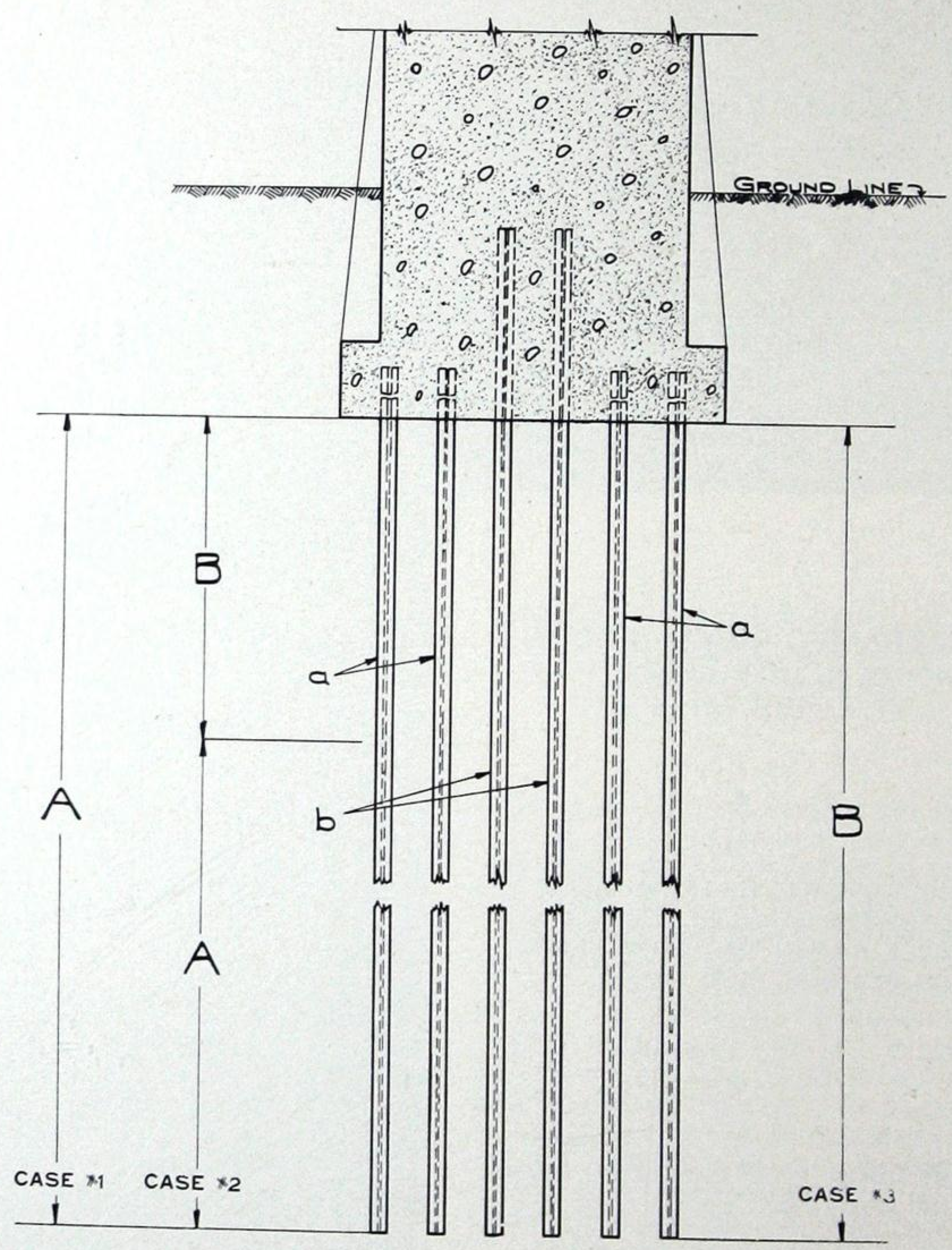
In general, the greatest efficiency is obtained by using the section having the largest overall dimensions for a given weight. To secure sufficient contact with the soil, in order to develop a reasonably high capacity per individual pile, it will be found that a pile with the necessary overall dimensions will have considerably more cross sectional area of metal than is required to carry the loads when acting as a column. Therefore the unit stresses in the piles themselves due to the direct vertical loads usually range between the relatively low values of 4,000 to 10,000 lbs. per sq. in. While it is usual practice to limit the maximum steel stress in building columns to 15,000 lbs. per sq. in., it is recommended that metal in the bearing piles be limited to a maximum stress of 12,000 lbs. per sq. in., due to the possibility of the loss of some metal on account of corrosion. The preceding limiting stresses are based on vertical loads only. Where combined bending and direct axial stresses occur, higher unit stresses are permissible.

The CBP sections have in general two uniform thicknesses of metal for each overall dimension of section. The lighter of the two sections is usually recommended for use in driving through uniform homogeneous materials under fresh water conditions. Where boulders are encountered, or where it may be necessary to pierce sunken logs or cribbing, the use of the heavier section is advisable. The use of the heavier section is also desirable under conditions of salt water exposure.

The principal difference between special CBP bearing pile sections and standard CB sections is that the bearing pile sections have webs and flanges of approximately uniform thicknesses, except in one or two instances where it was impractical to reduce the flange thickness to that of the web.

Unsupported Length or Slenderness Ratio:

Where steel piles are entirely surrounded by or encased in stable earth, they may be regarded as fully supported against lateral deflection throughout their full length. Where these piles project above



CASE 1
WHEN "A" IS SAND OR GRAVEL, STIFF CLAY OR OTHER FIRM MATERIAL, PILE CAN BE ASSUMED SUPPORTED FOR ITS ENTIRE LENGTH.

CASE 2
WHEN "A" IS AS IN CASE #1 AND "B" IS WATER, MUCK OR SOFT CLAY, USE AS UNSUPPORTED LENGTH FOR PILES (a) THE FULL HEIGHT OF "B," AND FOR PILES (b) AN UNSUPPORTED LENGTH OF 2/3 OF B, ON ACCOUNT OF RESTRAINT OF TOP OF PILES (b).

CASE 3
WITH "B" WATER, MUCK OR SOFT CLAY—FULL HEIGHT—FOR THIS CASE THE ONLY PERMISSIBLE METHOD OF DESIGN IS TO USE TYPE (b) PILES WITH UPPER ENDS FULLY RESTRAINED AND COMPUTED FOR AN UNSUPPORTED LENGTH OF 3/4 B.

NOTE:
PILE "a" IS CONSIDERED TO BE CAPPED ONLY, WHILE PILE "b" EXTENDS A SUFFICIENT DISTANCE INTO PIER TO BE CONSIDERED FULLY RESTRAINED. FULL RESTRAINT MAY ALSO BE OBTAINED BY FRAMING PILE INTO DEEP STRUCTURAL STEEL OR REINFORCED CONCRETE CAP.

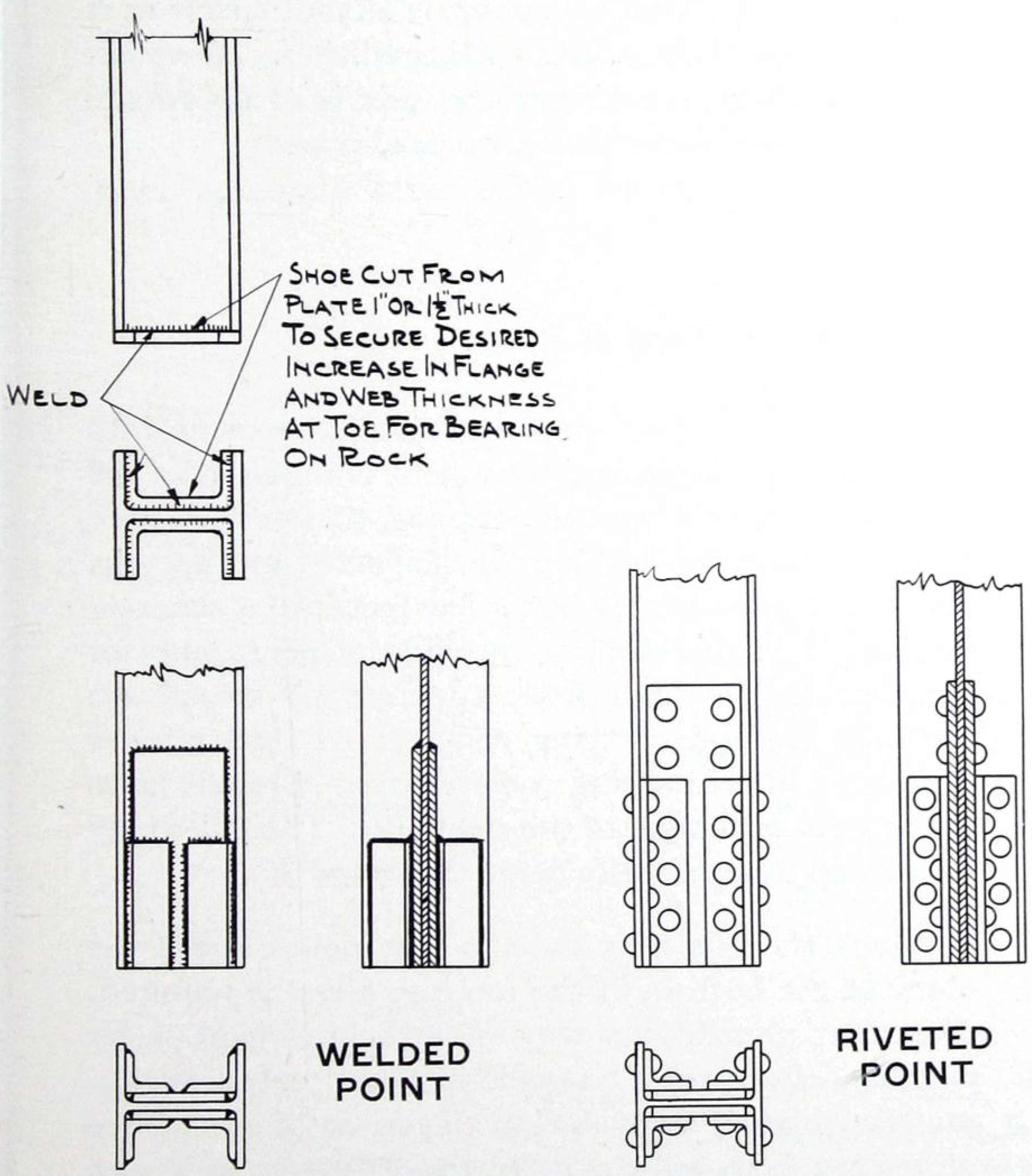
the ground line and form part of a special bent, the usual rules of structural design govern. Full lateral support below grade can be assumed for the columns under virtually all conditions, except such as where the pile is standing in a considerable depth of water, or where it penetrates through layers of very unstable material, such as peat, fluid muck, or very soft clay. They should be considered as unsupported laterally wherever they pass through these materials. Very little lateral support is required as the usual practice in bridge work is to proportion members which are intended to fix columns laterally, so that they are capable of withstanding a force equal to only 2½ to 3% of the direct axial load on the columns.

In cases where bearing piles are driven to rock overlaid by relatively unstable soil, very little lateral support can be assumed and in these cases, the piles should be designed as portals, with their tops restrained by adequate framing of either steel members or a heavily reinforced concrete cap.

See diagram on page 22 for typical conditions encountered in design.

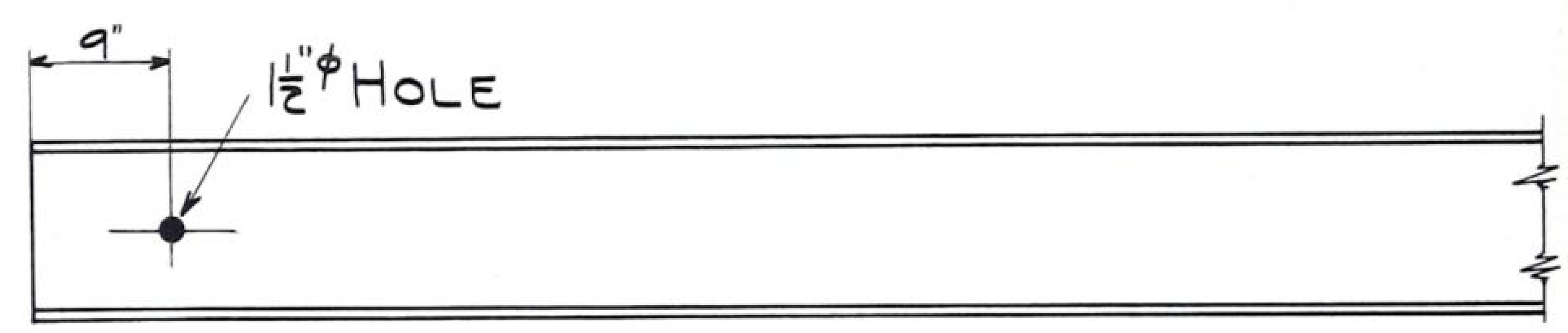
Bearing Capacity:

Following the reports of load tests and driving data, there is a summary of average sustaining values which may be used in determining the approximate bearing capacity of a pile. It is strongly recommended, however, that test piles be driven on every construction project. Where it is impractical to make actual load tests, the formulae as given elsewhere may be used to determine the safe bearing value of piles driven in sand, gravel, etc. Check tests should

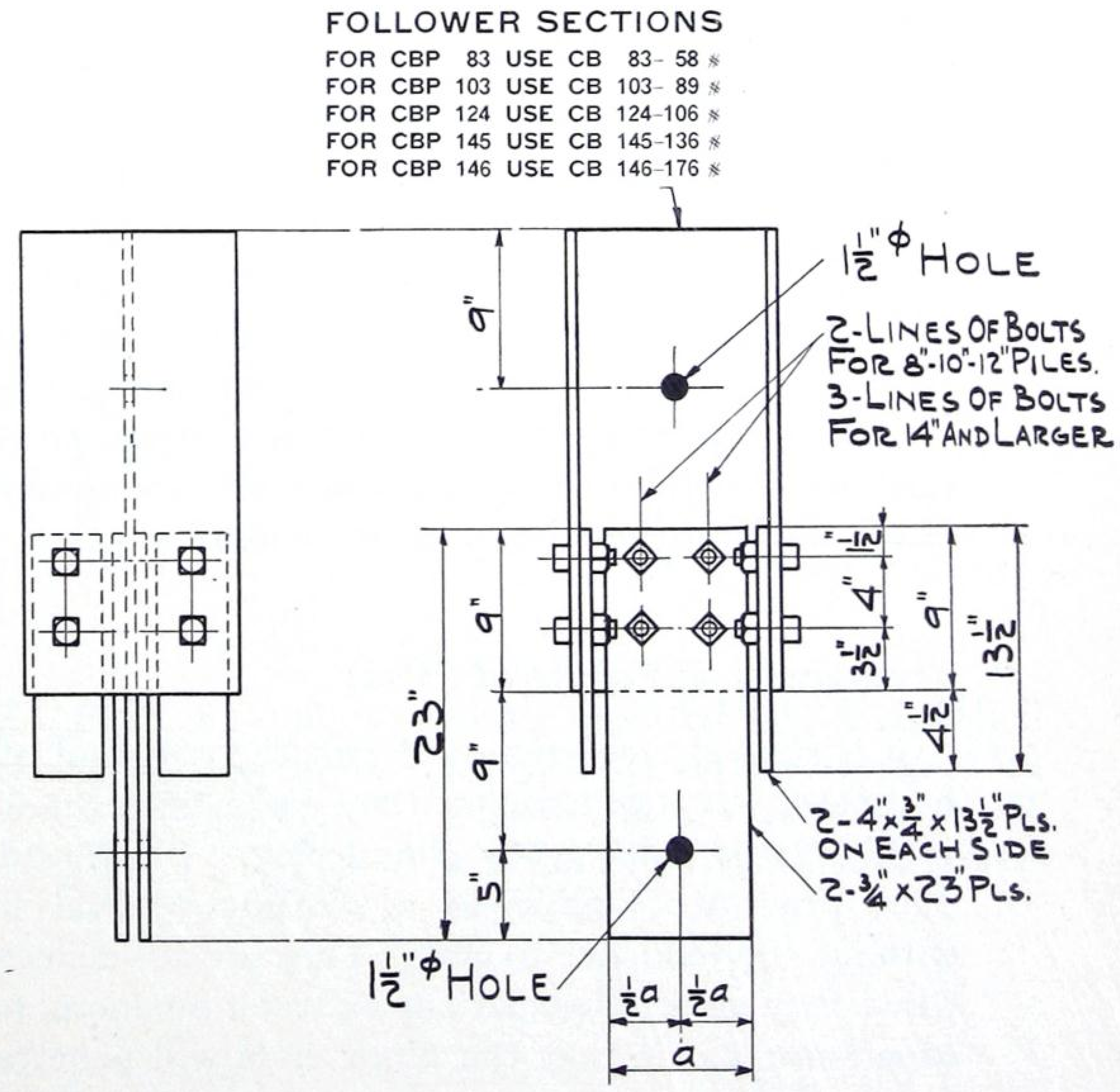


SUFFICIENT AREA OF PLATES AND ANGLES ADDED TO BRING PRESSURE BETWEEN GROSS AREA OF STEEL AND ROCK DOWN TO A RANGE OF 3000 LBS. TO 6000 LBS. PER SQ. IN. • WELDS OR RIVETS PROPORTIONED TO DEVELOP STRESSES OF 10,000 LBS. PER SQ. IN. ON ADDED STEEL AREAS. • THIS IS TO INSURE AGAINST ANGLES AND PLATES TEARING LOOSE DURING DRIVING

BUILT-UP PILE POINTS FOR DRIVING TO SOLID ROCK



IF ORDERED, PILES CAN BE FURNISHED WITH HANDLING HOLES AS SHOWN AT ONE OR BOTH ENDS OF SECTION.



FOLLOWER TYPE DRIVING CAP

always be made on piles driven in clays, silts, etc., as the static bearing capacity of piles driven in these soils varies considerably with their moisture content. The formulae will usually give lower safe values than those obtained by actual loading tests. This is indicated in many instances in the tabulations of load tests.

It is recommended that whenever possible several load tests be made either by the use of jacks or by building and loading platforms. The results from either method are satisfactory and practically identical, although the latter method introduces difficulties of applying the loads, balancing, etc.

Steel bearing piles should be driven through soil for their full effective length. Excavation below the level of footings, or the practice of drilling post holes for entering and erecting piles, should not be permitted. The piles should be supported by rigid leads or guide frames. Instances have come to light where post holes as deep as one-third the length of the pile were excavated. This resulted in the piles being driven only about two-thirds of their effective length, with consequent reduction in carrying capacity.

further into shale or soft rock than is the case where some form of pointed end is built up.

In cases where piles are driven to solid rock, the blunt ends of the piles may be increased in cross-sectional area by welding or riveting on suitable angles and plates. This method is shown on page 23. Good practice is to build up the ends of the piles so that the pressure between the steel and the rock ranges from 3,000 to 6,000 lbs. per sq. in. depending on kind of rock. Crushing strength of natural rock ranges from 6,000 to 18,000 lbs. per sq. in. when tested in relatively small cubes. Its capacity to sustain great intensities of load over limited areas is thus assured as long as the total load per unit of rock area tributary to the pile point does not exceed the total pressure usually permissible in foundations bearing on rock. Where steel piles are used as construction equipment, and are driven, pulled, and redriven a number of times, the use of a cast steel pile point is advantageous as it keeps the end of the pile in good condition. However, as stated before, pointing of the pile is of no advantage when used in permanent work.

Spacing:

Drawings of bearing pile installations shown in this booklet give examples of various pile spacings.

Class I piles, or those driven to rock or hardpan, may be spaced very closely; a practical limit being a center to center distance of at least twice the nominal size of a CBP section—i.e., a minimum of 20" center to center for a 10" CBP.

Class II piles, or those not driven to rock or hardpan, should not be spaced closer center to center than 2½ times their nominal size in order to get best results from groups. Where conditions permit, greater spacings are desirable as they allow the development of somewhat greater loads per individual pile.

Treatment of Points of Piles:

It is strongly recommended that the points of piles be left square and blunt as they come from the mill without any pointing or chamfering. Blunt ended piles penetrate readily in a straight vertical line without any tendency to cant. They are not deflected when they strike obstructions or small boulders, and experience shows that the blunt ends will penetrate

Treatment of Tops of Piles:

Where piles extend considerable distances up into concrete piers, no special treatment is required as the adhesion between the concrete and the steel is more than sufficient to develop the capacity of the pile. Where the pile extends but a few feet into a concrete footing, it is desirable to provide some means for transferring the load from concrete to steel. An excellent method of tying concrete to steel piles is by means of reinforcing rods inserted through holes in the webs or flanges of the steel pile. The holes may be burned to suit in the field. See page 29.

Where the pile terminates a few inches above the plane of the bottom of the footing, a cap is required. The most expeditious way of attaching caps is by welding. Caps may be made of plain plates, angles, punched plates, open steel grillages, or of special tee pieces cut from webs and flanges of beams, as shown on page 29. The head of the pile may also be filled out by any one of several other conventional means. After considerable long, hard driving, the top of the pile may be battered sufficiently to warrant cutting off a short length preparatory to attaching a cap.

Splicing:

The matter of the strength of splice in a given length of steel bearing pile is governed by several considerations.

If piles are restrained throughout their full length in firm soil, or where the pile constitutes one of a cluster, or the position of a splice is staggered in relation to splices in adjacent piles, and moderate driving is encountered, a splice need consist only of a full perimeter butt weld or preferably of simple web and flange plates welded on in the field.

Where the splices are all approximately at the same level and where hard driving is encountered, even though the piles are restrained laterally for their full length, the splices should be designed to develop approximately one-third of the full moment value of the pile.

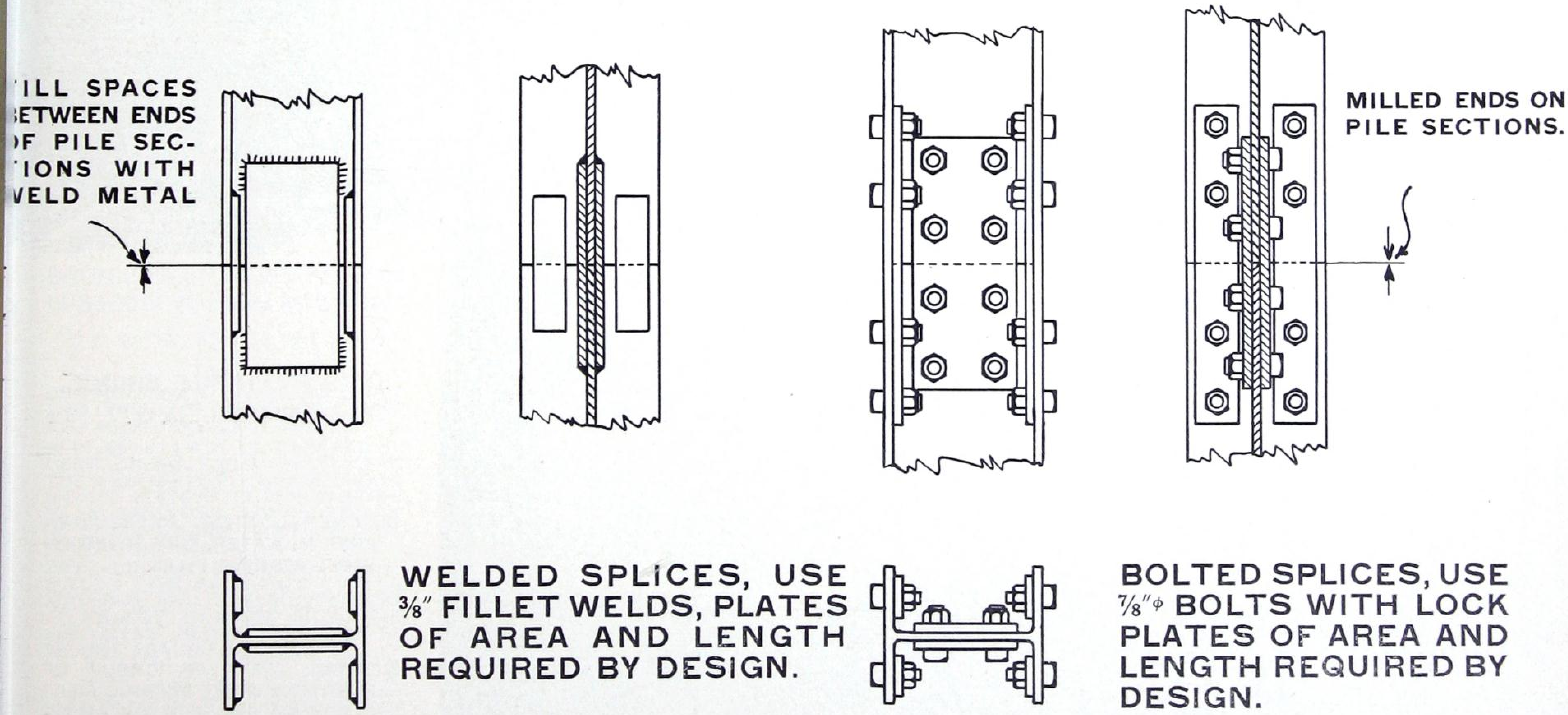
Where splices occur in long piles which are not braced laterally and especially where the piles form part of a trestle bent structure where they are subjected to considerable lateral forces, they should be designed to develop practically the full moment value of the pile section.

Where bolted splices are used, the ends of the piling sections should be milled to bearing. In the case of welded splices, the irregular ends of piling can be brought in contact and to bearing by means of welding in the field.

It is desirable that the flange splices be confined to the inner faces of the flanges, as any projections on the outer faces tend to force the soil away from intimate contact with flanges as the projections pass downward during driving. This tends to lower bearing values slightly, due to reduction of skin friction on flanges of piles.

Devices for Securing Increased Bearing Values:

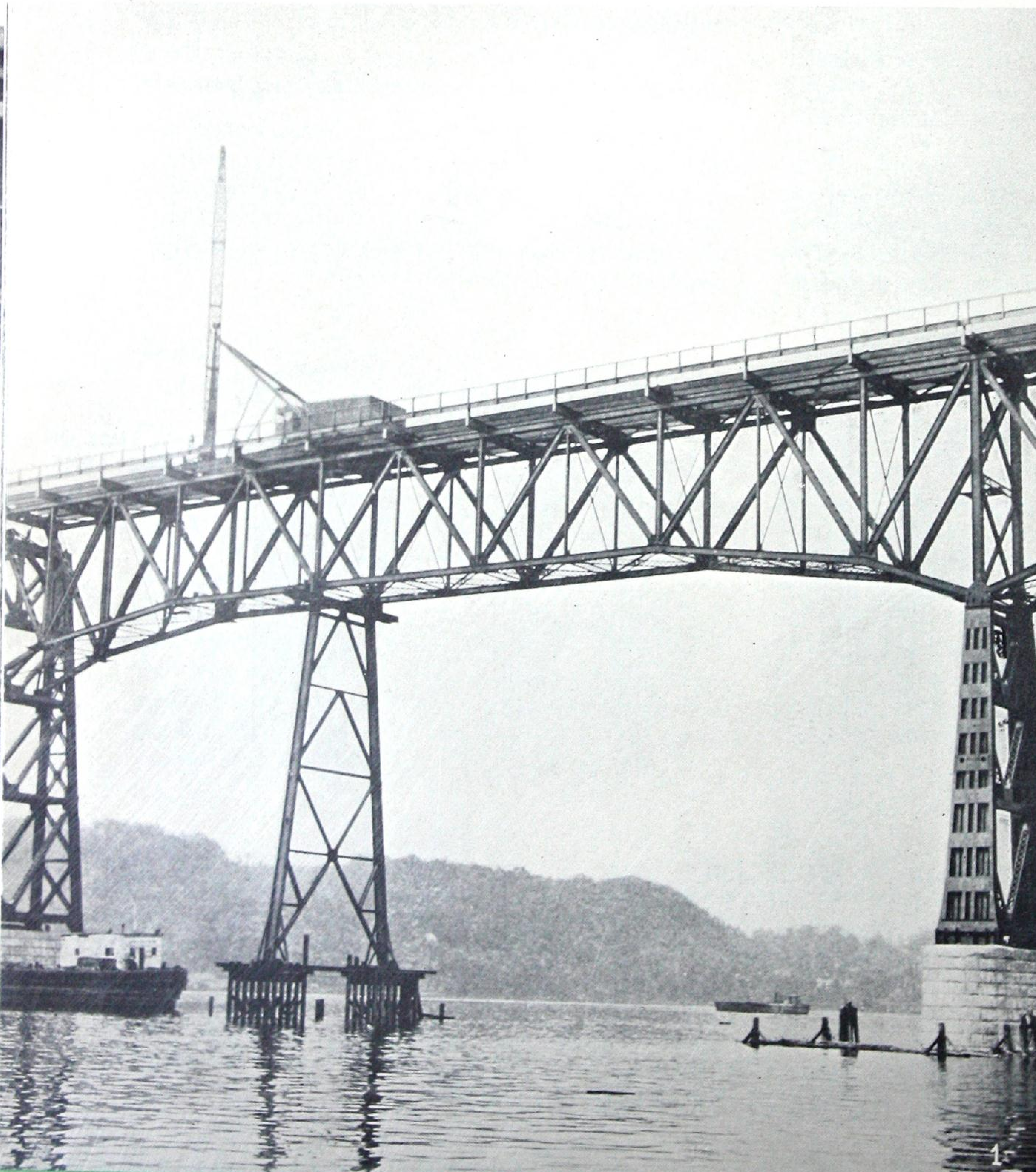
Many methods have been employed to obtain increased bearing values, such as welding short sections or parts of piling on each side of the pile near the point, attaching projecting shelf angles, placing rings of angles about the pile, building up the point with angles and plates, and other means.

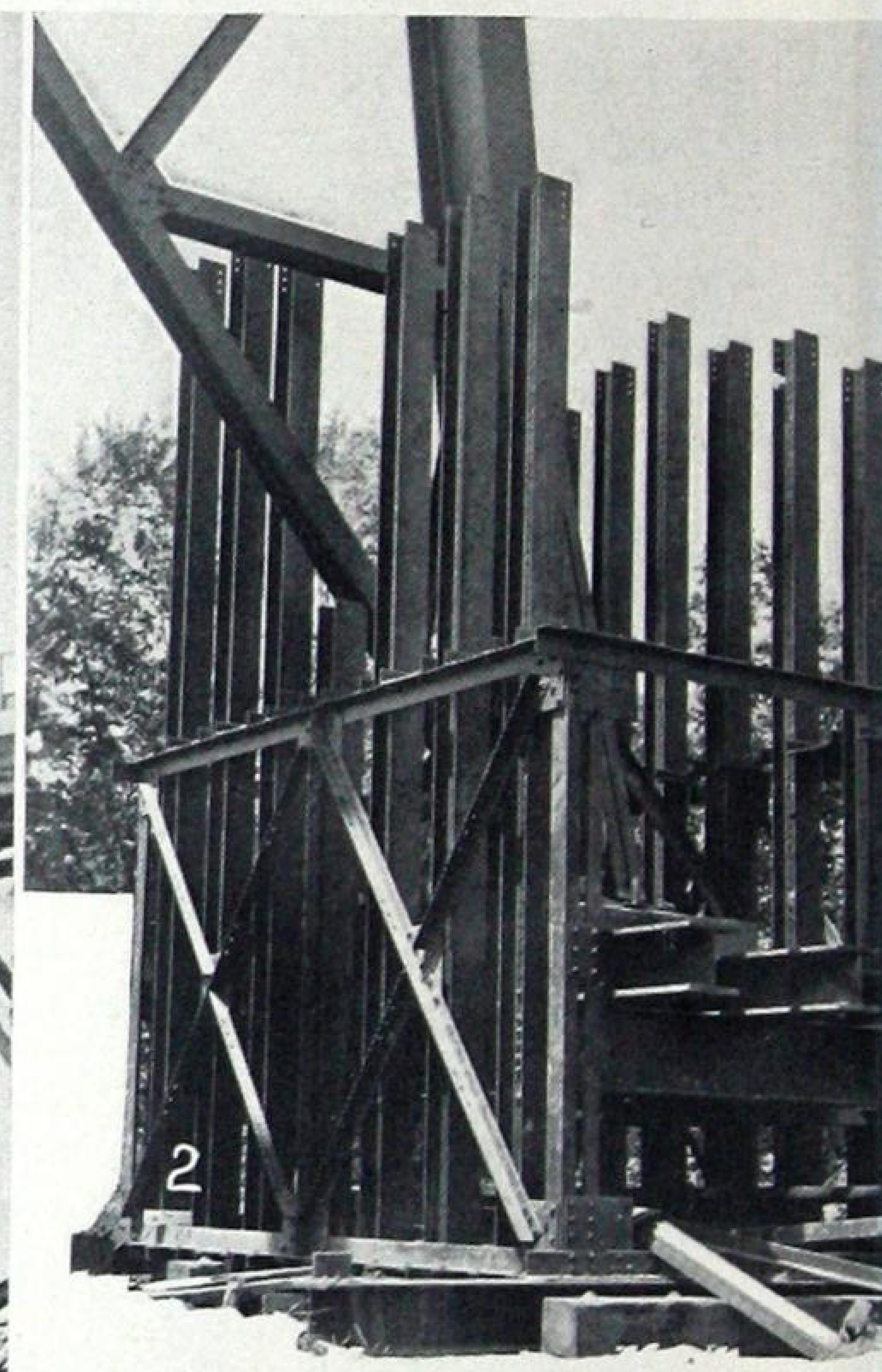


TYPICAL DETAILS OF PILE SPLICES

While many of these methods have resulted in considerable increase in bearing capacity, it is probable that sometimes the same increase could have been obtained at less cost by driving a greater length of plain piling to a deeper penetration.

Certain methods of increasing the bearing value, which indicate considerable merit for piles driven in sands and gravel, have been developed as shown in the tabulation of test results. These methods, however, become most effective and economical apparently only when applied at a distance of 15 to 20 feet above the pile point, and consist of boxing the **H** or **I** section for a length of 6 to 10 feet, see section **FF**, page 17. The pile may be boxed or built up into a rectangular section by welding plates between the outer edges of the flanges, or by filling the space between flanges with concrete, the concrete being held in position by means of steel rods welded between the flanges. The reasons for the effectiveness of this method are apparent in view of the phenomena observed when driving rolled steel section piles, as the boxing fills the partial void created 15 to 20 feet above the pile point.





RIP VAN WINKLE BRIDGE,
CATSKILL, N. Y.

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1. GENERAL VIEW. FALSEWORK BENT IN WATER, SUPPORTED ON STEEL BEARING PILES.

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2. DETAIL VIEW OF GROUP OF FOURTEEN STEEL BEARING PILES CARRYING ONE LEG OF FALSEWORK FRAME.

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DESIGNED BY
ROBINSON & STEINMAN,
ENGINEERS, NEW YORK CITY
HARRIS STRUCTURAL STEEL CO.,
FABRICATORS AND ERECTORS

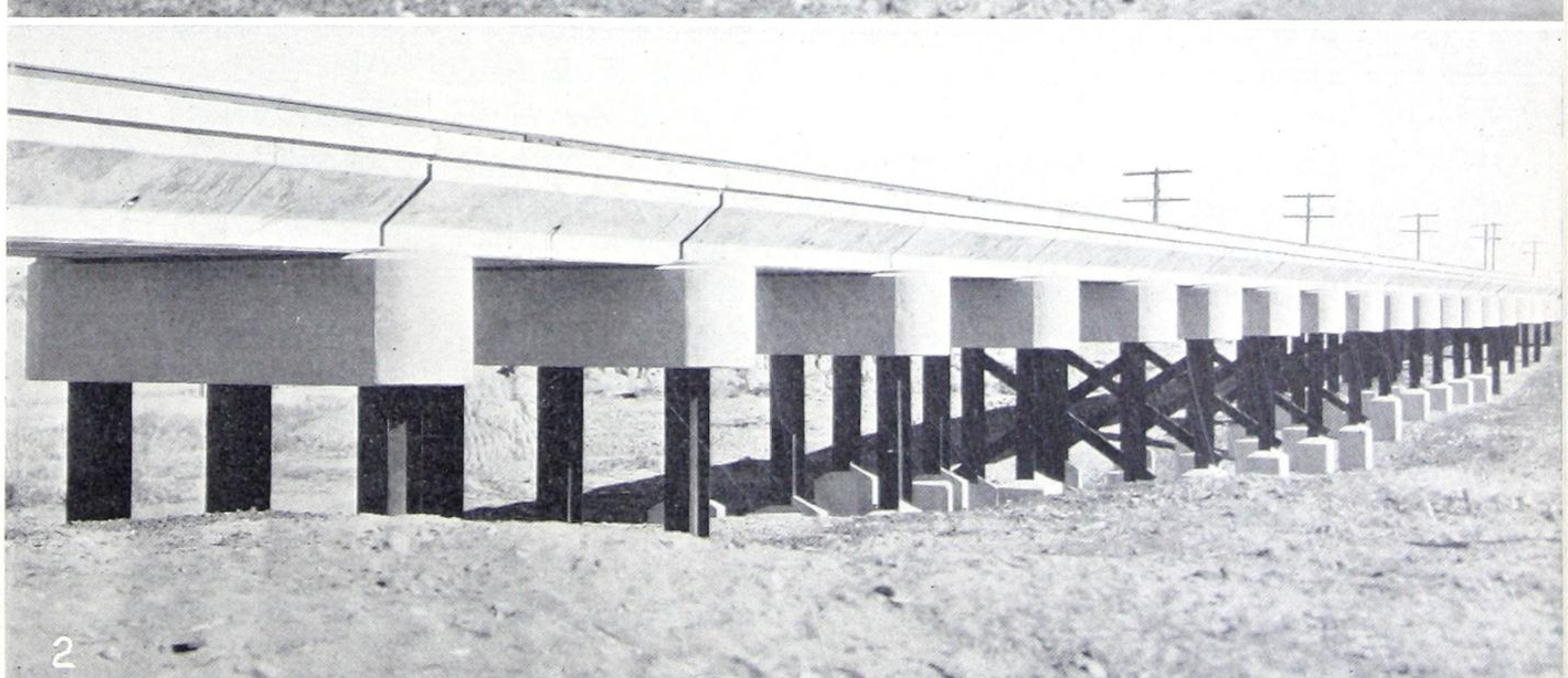
Driving Phenomena:

Both the relatively light double-acting steam or air hammer, and the heavy single-acting type hammer in the larger sizes, have been used successfully for driving steel bearing piles. Ordinarily no cushions are necessary between the top of the pile and the hammer. Under exceptional cases of extremely hard driving it may be desirable to use some form of driving cap. It can be one of the conventional cast steel type, or a built-up design as shown on page 23, which can be furnished for each size of pile. This head consists of a short length of CB section, of the same section number as the pile, but of considerably greater weight, with suitable guide plates and angles to hold it concentric with the head of the pile.

In general, the tops of the piles batter very little unless driven eccentrically, or are overdriven and hammered for considerable length of time after refusal.

In virtually all cases where CB section bearing piles

1



2

BRIDGE NEAR NEPESTA, COL.
MISSOURI PACIFIC RAILROAD

F. E. BATES, BRIDGE ENGINEER

•

COMBINATION STEEL BEARING PILE AND CONCRETE CAP TRESTLE BENT BALLASTED RAILROAD BRIDGE.

69 PILES 18″ CB 71 LB. ORDERED 59′ LONG, DRIVEN FROM 42′6″ TO 57′6″. THE SHORTER PILES FOR THE CROSS-BRACED BENTS AFTER PENETRATING 30′ OF SAND AND GRAVEL AND 10′ OF SHALE UNDER HARD DRIVING, RESTED SUPPOSEDLY ON ROCK.

THIS BRIDGE DESIGNED ORIGINALLY FOR PILES OF OTHER MATERIAL BUT IT WAS NECESSARY TO CHANGE TO STEEL TO OBTAIN SUFFICIENT PENETRATION TO BE SECURE AGAINST SCOUR.

•

1. NOTE 10″ 20 LB. CHANNEL CROSS-BRACING WELDED TO PILES AT CENTER BENTS. ALL BENTS HAVE CONCRETE CAPS 3′ DEEP EMBEDDED WITH TOP FLUSH WITH GROUND LINE. INDIVIDUAL CONCRETE ENCASEMENT OF PILES EXTENDS 4′ ABOVE THE EMBEDDED CAP.
2. BRIDGE HAS A TOTAL LENGTH OF 382′10″. IT IS CARRIED BY 23 TRESTLE BENTS. NOTE THAT 18 BENTS HAVE PLAIN VERTICAL PILES WITHOUT CROSS-BRACING.

have been removed after use, it has been found that the earth has been packed so tightly between the flanges at the lower ends that mechanical means had to be used to remove it. This compacting of earth is quite noticeable and extends upward for a distance of 10 to 12 feet from the point of the pile.

It is apparent that, during driving, the steel H type of pile grips the soil between the flanges thus forcing down and compacting the soil toward the lower end.

Usually, when CBP sections are driven as bearing piles, the level of the bottom of the excavation settles a few inches, and in many cases, it is possible to drop a piece of 2 x 4 down between the flanges and webs of the pile for a distance of several feet. This is contrary to the experience where the displacement types of piles are used, where the earth at the bottom of the excavation usually rises a distance of from a few inches to as much as several feet.

Handling and Driving CBP Section Bearing Piles:

Sections may be unloaded and stored at the site in the manner usually employed in handling similar structural material.

As shown in a number of illustrations, the piles can be set into position and driven by means of simple leads suspended from the boom of suitable hoisting equipment. Where test piles indicate fairly uniform driving conditions, and where the length of pile is determined by penetration desired rather than bearing capacity, most economical results are obtained by ordering the piles in lengths required from the mill.

When piles must be driven to a certain resistance, the lengths may vary considerably, especially in narrow river valleys, where there may be great differences in the characteristics of the underlying soil, even though the various groups of piles be driven in close proximity to each other. As these conditions require varying lengths of piles, one of the most economical methods is to drive them in what, for lack of a better term, may be called "series driving." This consists of driving a length of pile longer than that which is known to be required, which may be one piece or several pieces spliced together. The surplus length at the top is then cut off by burning in the field. This length is welded on to a long section of pile which is driven with the short portion downward and any surplus length at the top may again be cut off. In this manner, every lineal foot of section is used with very little waste and the splices are staggered at random throughout the pile clusters.

By this method there is no interruption in the driving as it permits making up long lengths of piles ahead of the driving by welding the sections as they lie on the ground.

When the "series method" is used, the piles are generally furnished in uniform lengths of 65 feet or less. The splicing arrangement permits their ready adaptation to a wide range of required penetrations. Lengths exceeding 120 feet have been driven by this method.

If bolted splices are used, both ends of the piling should be milled to bearing at the shop and suitable holes provided for the splice plates. By starting with one full length section and splicing on another full length, the projecting top of the pile can be cut off. The remaining short end is then bolted in place and driven as the point of the next length. This results in desirable staggering of splices, especially where the driven lengths are not quite uniform.

Driving Frames and Guides:

The relatively small overall dimensions of the CBP piles and their straightness permit the ready construction of simple rugged guide frames in enclosed or confined spaces.

Alignment and Spacing:

It is a characteristic of steel H section piles to drive straight and true to alignment. They show very little tendency to cant or shift laterally.

Advantageous Condition in Cofferdams:

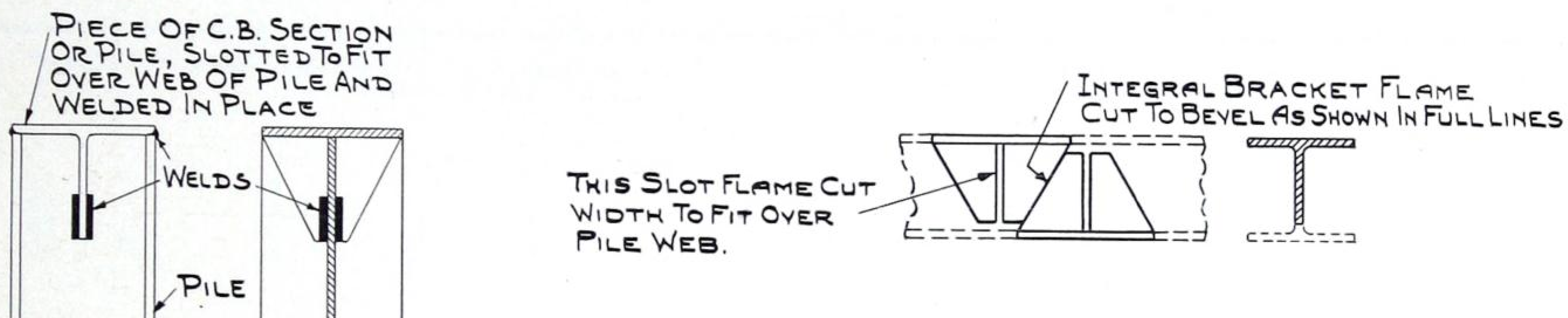
Where CBP sections are to be driven in the bottom of a cofferdam, it is not necessary to excavate below the theoretical bottom in order to compensate for earth which may be heaved up as a result of the driving of the piles. It has actually been found that where steel H sections are driven in a cofferdam, the level of bottom of the excavation sinks a few inches, rather than rises anywhere from a few inches to several feet as is often the case when displacement piles are driven. This condition eliminates considerable troublesome upheaval of soil with its attendant excavation, and loosening of bracing at the bottom of the cofferdam.

Capping:

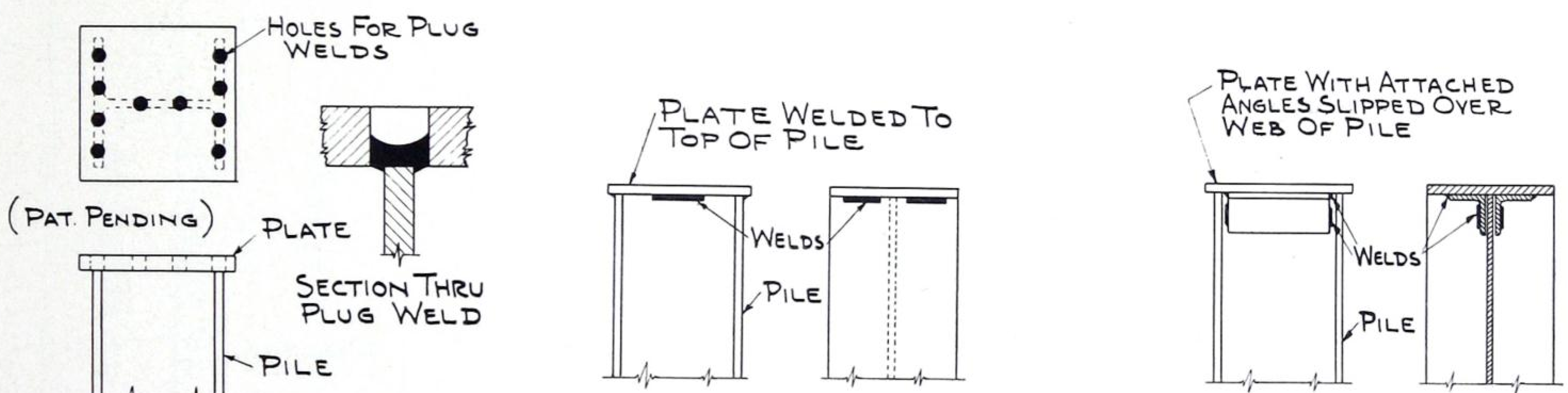
After the piles are driven to proper depth, penetration, or resistance, they can be cut off readily in the field with a torch and any of the various designs of caps as shown in this booklet welded into position, or else, the required holes can be burned in the sections and reinforcing rods may be laced through same as required.

Equipment:

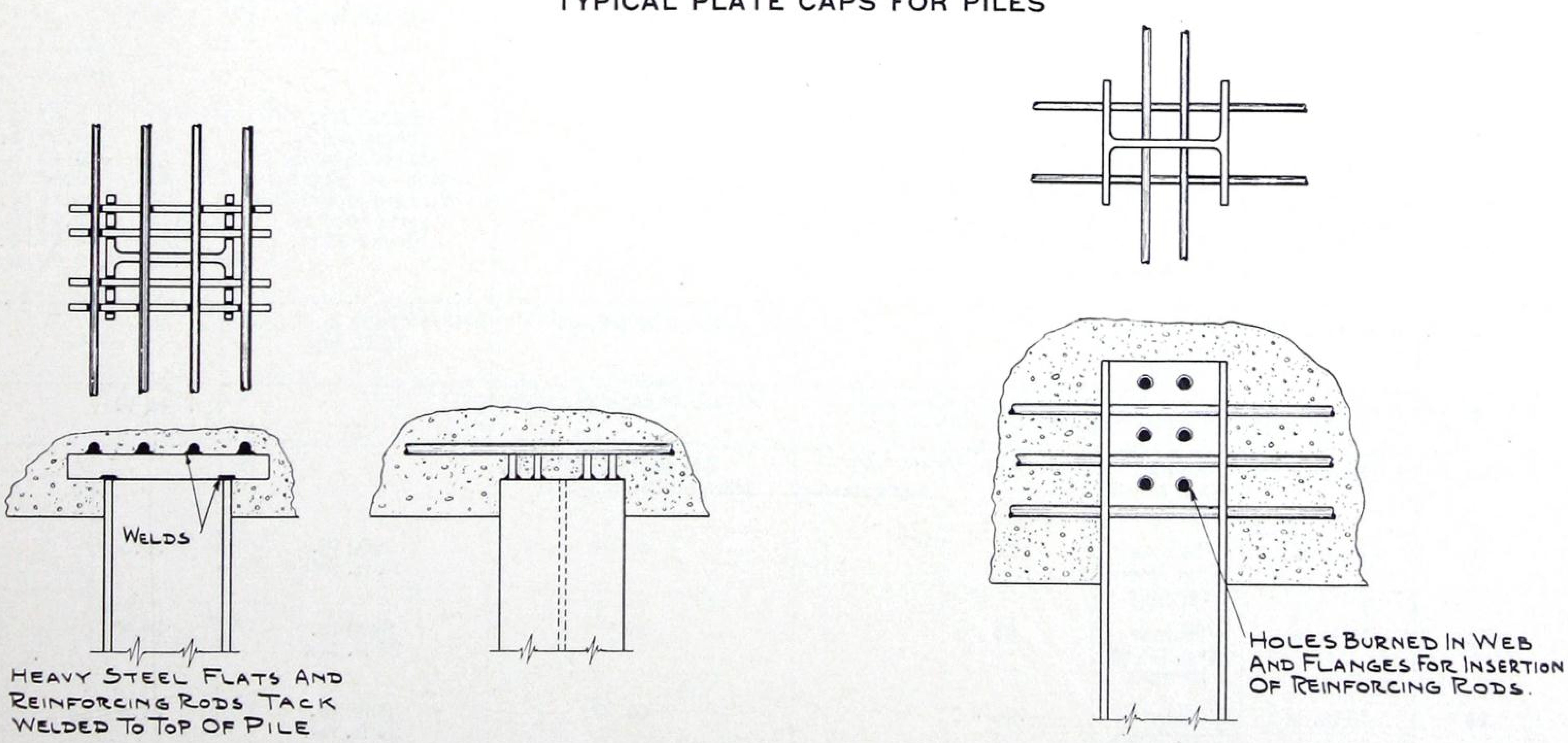
It will be noted from many of the illustrations that extremely heavy equipment, guides, leads, etc. are not required. The weight of an individual CBP section pile is not excessive and the most simple and elementary units of equipment will suffice for satisfactory installation. The photographs throughout this booklet show uniformly high standards of workmanship, with clusters of piles in perfect alignment. Illustrations of entire structures, such as combined pile-trestle bents where assembly of steel in the upper portion of structure is required, prove conclusively that steel bearing piles can be driven and held within very close limits, exactly in accordance with the requirements of plans and specifications.



DETAIL OF CAPS CUT OUT OF SECTION OF CBP PILE.



TYPICAL PLATE CAPS FOR PILES



SHALLOW FOOTING

DEEP FOOTING

ALTERNATIVE METHOD OF CAPPING PILES

TEST DATA AND BEARING VALUES

Load Tests:

Maximum test loads developed at various locations are as follows: In Nebraska, in 1932, on 8-inch H 32-lb. sections they ranged from 28 to 170 tons, the latter value being obtained at 44 feet penetration in sand and gravel; on 10-inch H 49-lb. sections, from 69 to 108 tons, with piles driven through sand and gravel with points resting in a clay bed; on 12-inch CB 65-lb. sections, up to 110 tons in tests conducted at the Bonnet Carre Floodway site in Louisiana, with a penetration of 122 feet in swampy alluvial layers of humus, clay-sand, with pile point in stiff blue clay; on 12-inch H 65-lb. sections they showed maximum capacity of 60.5 tons with 50 to 55 feet penetration in swamp mud, soft clay and sand, and stiff red clay at site of a bridge over Passaic River in New Jersey; and on 12-inch CB 110-lb. sections, near Lake Michigan at Gary, Indiana, 300 and 307 tons, with

SUMMARY OF TEST DATA •

Test Report No.	Kind of Section	Computed or Design Load	Max. Test Load in Tons	Settlement Under Load in Inches	Soil Condition	Kind of Hammer	Penetration in Feet	Penetration Per Blow at End of Driving in Inches
1	8 in. CB 33 lb. One piece Bottom pointed		28		Alluvial layers clay-sandy clay-humus and clay-sand, shells, clay-stiff blue clay	Vulcan No. 1	54	3.24
2	10 in. CB 49 lb. 4 pcs. 55 ft., 20 ft. 10 ft. and 10 ft. Bottom pointed		21.4 61.2 49.0 49.0	.56 .31 .68 .20	do do do do	do do do do	49 69 79 89	3.00 1.33 .71 .67
3	10 in. CB 49 lb. Boxed by welded plates between flanges 4 pcs. 55 ft., 20 ft., 10 ft. and 10 ft. square pyramidal welded point		30.6 61.2 58.1 61.2	.23 .19 .28 .35	do do do do	do do do do	49 69 79 89	2.86 1.20 .63 .60
4	12 in. CB 65 lb. 6 pieces 55, 20, 10, 10, 18.4 and 14.6 ft.		30.5 82.6 73.4 78.6 90.0 85.7 97.9 110.0	.11 .70 .34 .62 .46 .41 .52 .50	do do do do do do do do	do do do do do do do do	49 69 79 89 89 107.4 122 122	2.40 .92 .52 .41 .32 .27
5	20 x 20 in. Pointed precast concrete pile		177.5 128.5	.31 .42	do do	Vulcan No. 0 do	69.5 75	.24 with celotex cushion on pile
6	Wood pile butt 16 in. dia. point 8 in. dia.		110.2	.34	do	Vulcan No. 1	78.7	1.69
7	14 x 14½ in. CB 87 lb. 2 Sections 65 ft. each Bottom pointed Piles Nos. 2-4-7-9	* 34.0 tors *120.0 tons * 73.4 tors * 65.5 tons * 68.5 tons *115.0 tors				Vulcan No. 1 Single acting steam hammer Net Wt. 9600 lb. Wt. ram or striking parts 5000 lb. Stroke 33 in.	49 69 79 89 107 115 121 122	Pile Nos. 2 | 4 | 7 | 9 2.00 | 2.60 | 2.00 | 2.00 0.50 | 0.85 | 0.67 | 0.50 0.43 | 0.55 | 0.55 | 0.57 0.34 | 0.52 | 0.55 | 0.55 0.31 | 0.45 | 0.45 | 0.40 0.29 | 0.39 | 0.39 | 0.37 0.27 | 0.24 | 0.26 | 0.26 0.22 | 0.22 | 0.24 | 0.23
8	8 in. H 32 lb.	15.1 tons Eng. News formula			Sand & gravel	1450 lb. 15 ft. fall	30	.44
9	8 in. H 32 lb.		170	None	do		42 to 44	
10	8 in. H	16 tons Eng. News formula	58	Not appreciable	Sand & gravel pile point in clay bed			
11	8 in. H	15 tons Eng. News formula	81		do	2000 lb. 12 ft. fall	19.5	.60
12	10 in. H	28 tons Eng. News formula	69		do	2000 lb. 26 ft. fall	14.2	.875
13	10 in. H	29 tons Eng. News formula	108		do	2000 lb. 26 ft. fall	14.0	.775
14	8 in. H	16 tons Eng. News formula	63.5	Not appreciable	do			

:netration of 35 and 45 feet, respectively, in water-
:aring sand and fine gravel.

While load tests were not made because there was) question of the piles carrying their design loads,)", 12", and 14" CB sections have been driven to)solute refusal with penetrations ranging from 1.5 8 feet in shale or soft rock. Temporary false work r bridge loads, in excess of normal column loads for .e sections, have been applied for long construction :riods without signs of settlement.

The tables, pages 30-46, give in concentrated form, useful data from actual experience in testing and driving rolled steel section bearing piles. The first shows detailed experiences on a great number of projects located in widely scattered areas throughout the United States, also one large project in Germany. Following this are some condensed results under the caption, "Sustaining Values for Various Soil Conditions," and then a table showing recommended loads for various conditions of driving and soil and various depths of penetration of CBP sections.

SECTION • STEEL BEARING PILES

Pulling Resistance to Start Pile	Type of Structure Supported	Location and Date of Test	General Remarks
	Proposed Bridge	Bonnet Carre Floodway—1933 Near New Orleans, La.	Site of Test is a swamp. The general characteristic of material encountered is very tenacious stiff plastic clay with occasional strata of sand.
	do	do	
55 tons	do	do	Point stopped in packed sand at this penetration. Note higher capacities for all piles with points at this approximate level.
	do	do	
52.6 tons	do	do	
	do	do	
61.2 tons	do	do	
	do	do	
61.2 tons	do	do	
	do	do	
	do	do	
	do	do	
	do	do	
	do	do	Skin friction capacity—withdrawing slightly and reloading.
	do	do	
	do	do	
	do	do	do
	do	do	Tested in line and in conjunction with steel piles.
	do	do	do
	do	do	do
	Anchor Piles		These piles driven in line and in conjunction with other piles shown in this group. *Presumable calculated test loads interpolated from actual results on 12 x 12 in. CB 65 lb. driven to equal penetrations in same test. Values seem to indicate high point resistance for large pile at shallow depths with relative values decreasing with deeper penetration.
117.8 tons	Bridge	Mackinaw Bridge, Elkhorn River, Neb.	Pile Pulling Test. Pile first loosened by drop hammer.
	do	Gothenburg Bridge, Nebraska	Mill scale cracked and peeled during test. Pile loaded to elastic limit 35000 lb. per sq. in. Capacity testing equipment 300 tons.
	do	Fairbury, Nebraska	Pile tested for comparison between theoretical and actual capacity
	do	do	do
	do	do	do
	do	do	do
40.4 tons	do	do	Point resistance 23.1 tons taken as difference between maximum capacity and pull to lift. Point rested in clay bed.

Test Report No.	Kind of Section	Computed or Design Load	Max. Test Load in Tons	Settlement Under Load in Inches	Soil Condition	Kind of Hammer	Penetration in Feet	Penetration Per Blow at End of Driving in Inches		
15	8 in. H 32 lb.	10 tons by formula	30 35	None 48 hrs. None	Sand & gravel point in sand bed		26			
16	8 in. H				do		26			
17	8 in. H 32 lb.	8.6 tons Eng. News formula	28	None 24 hrs.	do		38			
18	10 in. H	10 tons 20 tons 25 tons 30 tons 35 tons			Sand—gravel Sand & gravel do do do do	Steam do do do do	20 32 37 45 52			
19	12 in. H 65.5 lb.	43 tons Eng. News formula	53 tons 69½ hours 60½ tons 18½ hours	Negligible do	6 to 9 ft. Cinders & sand 12 to 20 ft. Swamp mud 15 to 22 ft. Soft clay & sand 9 to 16 ft. Stiff red clay	No. 10-B2 McKiernan-Terry Double Acting Steam—15000 lb. per blow	50 to 55	.25		
								At 25 ft.	At 35 ft.	Final
20	10 in. G 41.5 lb. do do	8 tons 14½ tons 18 tons Eng. News formula	40 tons 75 100	.38 .44 .63	One month after completion hydraulic fill in tide flats. Top 15 ft. = new fill, sand and silt 10 ft. = mud 100 ft. = sand	4000 lb. drop hammer. Drop = 6 ft.	40 55 65	2.90 4.60 3.00	2.20 1.60 2.60	2.00 .65 .35
21	8 in. H 32 lb. do do	18 tons 12½ tons 16 tons All Eng. News formula	100 60 80	.44 .44 .31	do	do	60 65 50	4.80 4.80 3.60	3.50 2.20 1.80	.35 .90 .50
22	8 in. H 32 lb.	81 tons Eng. News formula	164		Filled ground of mixed sand and clay. High tide line 12 ft. below ground surface.	Steam drop hammer Weight of ram 2800 lb.—Drop 10 ft. and 15 ft.	36	20 ft. in few blows 25 ft.—2 in. per blow 10 ft. drop 36 ft.—.417 in. per blow 15 ft. drop		
23	8 in. H 32 lb.	15 tons Eng. News formula	58	None	Dry gravel & clay	3400 lb. Drop hammer. Drop = ?				
24	8 in. H 32 lb. with 2 ft. 10 in. pcs. of H welded to each flange 20 ft. above bottom of pile	30 tons Actual design 22.77 tons Eng. News formula			do	do	20			
25	8 in. H 32 lb. with 3 ft. 6 in. pcs. of H welded to each flange 20 ft. above bottom of pile	30 tons Actual design 19 tons Eng. News formula			do	do	25			
26	8 in. H 32 lb.	30 tons Actual design 20 tons Eng. News formula	60	None	do	do	36			
27	8 in. H 32 lb.	30 tons Actual design 20.1 tons Eng. News formula			do	do	38			
28	12 x 12 in. CB 110 lb. 60° Point	75 to 80 tons	225	.24*	Water bearing sand fine gravel	Vulcan No. 1	35	.11		
29	do 12 x 12 in. CB 110 lb. 60° Point do	75 to 80 tons	300 200 307	2.03 .18 1.56	do do do	do do do	35 45 45	.11 .11 .11		

Pulling Resistance to Start Pile	Type of Structure Supported	Location and Date of Test	General Remarks
	do	Pender, Nebraska	Maximum load not determined as one anchor pile pulled out.
15 tons. 48 hrs. 17.5 tons max.	do	do	Anchor pile carrying half load preceding test.
	do	Wood River, Nebraska	
	do	Clarks Bridge, Columbus, Nebraska	
	do	do	Average load capacity for each of 12 piles computed by Formula.
	do	do	
	do	do	
	do	do	
Average for 28 piles, 50 to 60 tons to pull	Falsework bents	Passaic River Bridge, N. J. East Side of River April, 1931	(Note 1) Data furnished to American Institute of Steel Construction by McClintic-Marshall Corporation.
	Test pile	Seattle, Wash., Feb. and March, 1931 M. S. Farwell, Bethlehem Steel Co. 3 Test Piles	(See Note 1) City of Seattle required the test piles to be loaded to twice the design load. Allowable settlement under this load was .01 inch per ton of load applied, provided this settlement occurred during the first 48 hours after completion of the loading and no further settlement occurred after this. From "Discussion of Steel Pile Foundations for Highway Bridges," by M. S. Farwell.
	do		
	do		
	do	do	
	do		
	do		
	do	Oakland, Calif., June, 1929 M. S. Farwell, Bethlehem Steel Co.	(See Note 1) Cast steel driving head fitted to leads and top of pile. Loads of 100, 120 and 140 tons were applied by jacks and after release the pile would spring up about ⅜ inch. Jacks pumped to 160 tons, flanges of pile under driving head began to cripple. At 164 tons or 35,300 lbs. per sq. in. on pile failure increased to such a degree that test was discontinued. Full pressure maintained for two hours, upon release pile raised about ½ inch.
	do	Pacific Coast, May, 1929 M. S. Farwell, Bethlehem Steel Co.	(See Note 1) Some of piles buckled and folded down on themselves at a point about 4 feet below the ground.
	do	do	(See Note 1) Pile buckled just above top of attached short lengths of H beams.
	do	do	
	do	do	
	do	do	
100 tons to start	Test Load	One mile from Lake Michigan at Gary, Ind. Water bearing 4 ft. below surface. Dec. 4, 1931.	American Bridge Co., Western Division Erecting Dept., conducted tests to determine safe loads for erection falsework.
135 tons max.	do	do	*First settlement represents theoretical elastic deformation of pile as computed by American Institute of Steel Construction.
	do	do	
	do	do	

Test Report No.	Kind of Section	Computed or Design Load	Max. Test Load in Tons	Settlement Under Load in Inches	Soil Condition	Kind of Hammer	Penetration in Feet	Penetration Per Blow at End of Driving in Inches
30	12 x 12 in. CB 65 lb. 45° Point Reinforced by 4 4 x 4 x ⅝ in. angles	35 tons direct vertical 50 tons all combined forces	Safe capacity computed by Eng. News formula 104 tons		El. 720.2 River bed El. 715.7 Fine river silt El. 700.7 Blue gumbo El. 696.7 Coarse sand El. 681.7 Fine sand shale & blue soapy shale below	No. 0 Warrington Vulcan for bulk of work. Some driving with No. 1 hammer.	29.5 below El. 706 which is bottom of pier	Care was necessary t stop driving as soon a pile reached the shal so as to avoid injurin the pile with No. single acting hamme used.
31	do	do			El. 739.33 Ground El. 724.33 Fine slit El. 699.33 Blue gumbo El. 689.33 Coarse sand El. 684.33 Fine sand El. 674.33 Coarse sand & fine gravel El. 666.83 Fine gravel El. 657.83 Coarse sand gray shale below	No. 1 Warrington Vulcan Hammer for all driving.	53.5 below El. 706 which is bottom of pier	Pile considered wel seated when it drov only 1 in. under 2 blows from No. single acting hammer
32	do	do			Probably similar to Pier No. 7	No. 0 Warrington Vulcan for bulk of work. Some driving with No. 1 hammer.	53	do
33	10 in. H 49.5 lb. 4.9 ft. long	6.6 tons All values computed with Eng. News formula 20.8 tons 30.0 tons 31.0 tons	Sand box Time for loading 2½ hours 60	.25	Sand & gravel	Vulcan No. 2,100 lb. steam pressure driving time 51 minutes to depth of 40 ft.	10 15 20 25 30 32 34 38 40	1.00 .86 .75 .60 .25 .21 .17 .14 .13
34	8 in. H 31 lb. Plain end		65		Fine sand and water	Raymond Concrete Pile Rig	56.5	.13
35	8 in. H 31 lb. 4-8 x 8 in. Angles riveted 4 ft. from bottom forming 16 x 24 in. shelf area		37.5		3 ft. fill and peat, 13 ft. soft clay and sand, 19 ft. hard coarse sand with little clay and sand.	Wood Pile Rig	35	.14
36	8 in. H 32 lb.	30 tons	60				35	
37	10 in. CB 49 lb.	54.5 tons*			Old fill of gravel & clay at top. Original gravel below.	Vulcan No. 1 single acting steam hammer 5000 lb. Weight of striking part of hammer. Average drop 3 ft. 6 in.	19 24 30	.40 .26 .14
38	do	34.5 tons*			Old fill of gravel & clay at top. Heavy clay below.	do	14 19 24	.86 .43 .28
39	do	34.5 tons*			Fairly loose gravel.	do	14 19 24 30 34 40	.52 .31 .22 .16 .20 .28
40	do	33.5 tons*			Fairly loose gravel.	do	14 19 24	.52 .36 .29
41	do	28.5 tons*			Fairly loose gravel.	do	19 24 30 34	.29 .29 .29 .36
42	do	48.5 tons*			Clay and hardpan. Loose gravel. Hardpan.	do	19 24 30 34	.27 .26 .15 .17
43	10 in. CB 49 lb.	67 tons			25 ft. sand with clay, 37 ft. sand and gravel.	McKiernan-Terry 9-B2 Hammer	45	.005
44	do	67 tons			8 ft. sand, 51.8 ft. sandy gravel, 0.2 ft. trap rock.	do	48	.005
45	do	66 tons			52 ft. sand and coarse gravel.	do	43	.0063
46	do	65 tons			3½ ft. loam, 39 ft. sand and gravel, 5½ ft. cemented gravel, 8 ft. sand and gravel.	do	44	.0075

Pulling Resistance to Start Pile	Type of Structure Supported	Location and Date of Test	General Remarks
	Bridge Pier No. 6 126 steel piles	Kansas River Bridge, So. 7th St. Kansas City, Mo.	Some early driving was done with 9-B-2 McKiernan-Terry Hammer which was not used in later portion of work, as after refusal with same, four or five feet additional penetration could be secured with No. 0 Warrington Vulcan Hammer. Piling was driven with close fitting cast semi-steel cap and there was very little evidence of battering and not much upsetting of pile heads. It was found as driving of piles proceeded that the borings were a very fair index to soil strata conditions actually existing. A few piles were driven without web point angles with no noticeable difference in rate of penetration.
	Bridge Pier No. 7 334 ft. north of Pier No. 6 126 steel piles	do	A 6 in. to 2 ft. recession or sinking of the bottoms of excavations for piers was noticed in driving these piles. This was variously accounted for by those concerned. Numerous piles were given 100 blows without perceptible movement. The job was straight driving, no jets being used.
	Bridge Pier No. 8 273 ft. north of Pier No. 7. 83 steel piles in 5 rows. One outer row on stream side battered 1½ in. in 12 in.	do	Data from article "The New 7th St. Traffic Way, Kansas City," by LaMotte Grover, Engineering News-Record, October 19, 1933. and report by Carnegie Steel Company Kansas City representative, November 20, 1933.
	Bridge	Santa Clara River near Montalvo, Calif.	Data furnished by Highway Department at Sacramento, Calif. By means of sand box, loads were applied up to 60 tons, which, after preliminary settlement, was held for 24 hours without any further settlement. During loading settlement was reported as ⅛ in. at 50 tons and ⅛ in. at 55.7 tons with final settlement of ¼ in. at 60 tons.
	Sewer Department Warehouse	Worcester, Mass., Oct. 22, 1931	Test by L. W. West, Consulting Engineer for Eastern Bridge & Structural Company.
	New Incinerator Building	Worcester, Mass., Nov. 12, 1931	
	Bridge	over A.T.& S.F. tracks near Merced, Cal.	Eng. News-Record Sept. 10-31. C. H. Purcell, State Highway Engr.
	North Abutment 140 CB Piles	Bridge over Great Miami River, U. S. Route No. 25, Dayton, Ohio. Built by Maxon Construction Co., Dayton, Ohio.	Data furnished by Mr. L. B. Gamble of State Highway Division Engineers Office, near Middletown, Ohio. All piles were driven 3 ft. center to center and capped with steel plates 5 to 5½ ft. below the stream line with tops of piles extending 9 to 18 in. into the concrete pier caps.
	South Abutment 149 CB Piles	do	Specifications stated that "the maximum load on 14 in. to 16 in. timber, concrete or shell piles or 10 in. H-beams should not exceed 30 tons and must not exceed a maximum of 35 tons per pile".
	Pier No. 1 152 CB Piles	do	Specifications stated that where steel H piles are used in dry ground "they shall be protected from corrosion at the ground line by means of concrete encasement extending at least 3 ft. below and 1 ft. above the ground". Note that a total of 900—10 in. CB-49 lb. Steel H Piles were driven on this project.
	Pier No. 2 150 CB Piles	do	*All capacities computed by formula $P = \frac{1.5\ WH}{S + 0.1}$ The gravel was of such character that it was impossible to get more than 8 in. or 9 in. penetration with either concrete or wood piles.
	Pier No. 3 151 CB Piles	do	do
	Pier No. 4 158 CB Piles	do	do
	21 Pile bent No. 1 24 Pile pier No. 2 32 Pile pier No. 3 30 Pile bent No. 4	Bridge No. J896 over Black River on State Route No. 67, near Hendrickson, Butler Co., Missouri—1933.	The two concrete center piers and two concrete abutments were supported by a total of 107 piles—10 in. CB 49 lb. driven to a resistance of ⅛ in. to ⅞ in. penetration for the last 100 blows. One pile under each pier or abutment was selected as representative of the group from which it was taken. The log of soundings and complete driving records for all of the 107 piles furnished by the Missouri State Bridge Dept. Design load based on Engr. News Formula, $P = \frac{2E}{S + 0.1}$

Test Report No.	Kind of Section	Computed or Design Load	Max. Test Load in Tons	Settlement Under Load in Inches	Soil Condition	Kind of Hammer	Penetration in Feet	Penetration Per Blow at End of Driving in Inches
47	10 in. CB 49 lb.	67 tons			3 ft. sand, 31.6 ft. sand and gravel, 14 ft. trap rock, 3 ft. clay and trap rock, 14 ft. trap rock and gravel, 18.8 ft. clay, sand and gravel rock.	McKiernan-Terry 9-B2 Hammer	63	.005
48	do	67 tons			2 ft. sand, 31 ft. sand and gravel, 0.3 ft. trap rock.	do	32	.005
49	do	67 tons			7 ft. sand, 19 ft. sand and gravel and boulders, 0.8 ft. trap rock.	do	25	.005
50	do	69 tons			8 ft. sand, 19 ft. sand, gravel and boulders, 0.7 ft. trap rock.	do	25	.0025
51	do	69 tons			6 ft. sand, 26.4 ft. sand, gravel and boulders, 14 ft. ledge rock, 5.3 ft. gravel, 0.3 ft. trap rock.	do	38	.0025
52	do	67 tons			5 ft. sand, 37.8 ft. sand and gravel, 3.2 ft. trap rock	do	44	.005
53	do	67 tons			36.4 ft. sand and gravel, 2.1 ft. lime stone ledge, 1.0 ft. clay, 2.0 ft. clay and trap rock, 1.0 ft. trap rock.	do	51	.005
54	do	67 tons			22.5 ft. sand and gravel, 2 ft. rotten ledge, 15.4 ft. sand and gravel, 5.6 ft. rotten trap rock.	do	41	.005
55	do	69 tons			38.6 ft. sand, gravel and boulders.	do	19	.0025
56	do	67 tons			60 ft. sand and gravel, 3.2 ft. trap rock and soft limestone.	do	66	.005
57	do	67 tons			20.2 ft. sand and gravel, 3.6 ft. trap rock.	do	26	.005
58	do	67 tons			7 ft. sandy loam, 23 ft. sand and gravel, 1 ft. trap rock.	do	31	.005
59	do	67 tons			5 ft. sandy loam, 25 ft. sand and gravel, 1.9 ft. trap rock.	do	29	.005
60	8 in. CB 83-33 lb. 2 pieces—25 ft. and 20 ft.		20 loaded for 48 hrs. 30T—15 min. 40	.077 .117 Failure	30 ft. loam and silt, 12 ft. sand and loam, 1.5 ft. clay, 1.0 ft. sand and loam, 7.0 ft. clay, 3 ft. sand and clay, 5 ft. sand and loam, 16.5 ft. clay.	Vulcan No. 2, single acting, 3000 lb. Ram, Developing 7260 Ft.-Lbs. per blow.	43	.650
61	8 in. CB 83-33 lb. Batter pile 11° to Vert. 2-25 ft. Sect.				do	do	48.5	.575
62	8 in. CB 83-33 lb.				11 ft. sandy loam, 1 ft. sand, 38 ft. clay.	do	48.5	.706
63	do		20 30 35 40 45 49	.0781 .1444 .1562 .2032 .25 Total Failure	do	do	49.5	.520
64	14 in. CB 95 lb.		31.68 43.94 50.07 62.33 0.00 62.33 68.46 86.85	.05 .125 .200 .500 .350 .700 .85 1.55	Hill clay mixed with sand of varying amounts. Fairly uniform except several thin strata of sand were encountered.	Vulcan No. 1	20 25 30 35 40 45 53	1.2 1.0 0.63 1.33 1.33 0.71 0.44

Pulling Resistance to Start Pile	Type of Structure Supported	Location and Date of Test	General Remarks
	4 Pile bent No. 1	Bridge over Black River on State Route No. 34, about 1 mile west of Leeper, Wayne Co., Missouri—1933.	
	4 Pile bent No. 2	do	
	4 Pile bent No. 3	do	
	4 Pile bent No. 4	do	
	4 Pile bent No. 5	do	The data which was furnished by the Missouri State Bridge Dept. consisted of copies of all soundings and a complete pile driving record for each pile. Because of remarkable uniformity of results, one pile record was selected under each bent or pier as being typical of all piles on that particular group. Piles for piers driven approximately 3 ft. c. to c. and for bent 6 ft. 8 in. centers, all piles capped with piece of 10 in. CB-49 lb. notched to fit over web of pile and welded. Piles for bents incased in concrete from a point 3 ft. above ground to 4 ft. below, a total of 7 ft. Piles under pier extended 4 ft. into pier caps. Average penetration for last 100 blows was $\frac{1}{4}$ in. to $\frac{1}{2}$ in. All capacities under "Design Load" computed by Engr. News Formula, $P = \frac{2E}{S + 0.1}$ A total of 132—10 in. CB-49 lb. piles were used. List and Clark, Kansas City, Mo., were the general contractors.
	4 Pile bent No. 6	do	
	4 Pile bent No. 7	do	
	4 Pile bent No. 8	do	
	16 Pile pier No. 9	do	
	24 Pile pier No. 10	do	
	24 Pile pier No. 11		
	24 Pile pier No. 12	do	
	12 Pile abut. No. 13	do	
	Test pile No. 2	East Bank of Ouachita River, Monroe, La., Aug. and Sept., 1934.	Pile No. 2 was first tested with sustained load of 20 tons for 48 hrs. It was then raised to 30 tons, which was held for 30 min. It was apparent that no appreciable settlement was to occur, and it was raised to 40 tons, resulting in continuous settlement or failure.
45.15 Tons (Failure)	Test pile No. 3	do	
38.57 Tons (Failure) No. 1 55.0 Tons (Failure) No. 2	Test pile No. 4	do	Pile No. 4 was tested with pulling load in increments of 2 tons, $7\frac{1}{2}$ min. intervals, continuous movement occurring when load was increased from 39 to 41 tons. The second test on pile No. 4 was made when it had been allowed to set 4 days after first test. Failure occurred at 55 tons pull. The pulling resistance of pile No. 4 was only 15% less than bearing value of pile No. 5. All these tests were conducted by the U. S. Engineer Office, Western Area, Monroe, La.
	Test pile No. 5	do	
	Test pile No. 2	Old B. & B. Yard, Missouri Pacific Ry., Little Rock, Ark. Driven—July 27, 1933 Tested—Aug. 3, 1933	Information covering tests No. 64 to 71 furnished by F. E. Bates, Bridge Engineer, Missouri Pacific R. R., St. Louis, Mo. Test loads and settlements given are all for maximum length of pile penetration in a given test. Sand strata occurred at penetration of 30 and 57 feet, as indicated by driving resistance.

Test Report No.	Kind of Section	Computed or Design Load	Max. Test Load in Tons	Settlement Under Load in Inches	Soil Condition	Kind of Hammer	Penetration in Feet	Penetration Per Blow at End of Driving in Inches
65	16 in. CB 83 lb. With angles		31.68 43.94 50.07 0.00 50.07 56.20 62.33 68.46 74.59 125.8	.075 .150 .200 .075 .200 .225 .350 .450 .625 3.100	Hill clay mixed with sand of varying amounts. Fairly uniform except several thin strata of sand were encountered.	Vulcan No. 1	20 25 30 35 40 45 53	0.92 0.44 0.41 0.86 0.60 0.55 0.32
66	14 in. CB 95 lb. With angles		31.68 43.94 56.20 62.33 68.46 74.00	.075 .100 .200 .350 .600 Failure	do	do	20 25 30 38	0.62 0.67 0.52 1.10
67	16 in. CB 83 lb.		31.68 43.94 56.20 62.33 68.46 73.47	.075 .100 .200 .325 .625 Failure	do	do	20 25 30 38	1.70 0.92 0.56 0.56
68	14 in. CB 95 lb. Spliced with 18 ft. Section cut from pile No. 8		31.68 50.09 0.00 50.09 62.36 0.00 62.36 74.63 0.00 74.63 111.45 0.00 111.45 135.99 0.00 135.99 160.54 0.00 160.54 185.08 0.00 185.08 203.47 0.00 Anchor pile failed	.050 .100 .050 .100 .150 .075 .150 .175 .100 .200 .300 .125 .300 .400 .175 .425 .525 .250 .575 .700 .375 .775 .900 .475 Total 0.9	do	do	53 56 59 60	0.23 0.24 0.22 0.14
69	16 in. CB 83 lb. With angles, spliced with 18 ft. section cut from pile No. 9		Loads same as Test 68. Anchor pile failed after load of 197.2 tons.	Settlements practically same as Test 68 for any given load, even though this pile driven 12 ft. deeper.	do	do	53 55 60 65 72	..... 0.23 0.13 0.25 0.24
70	24 in. Concrete		31.68 68.46 86.85 105.27 123.66 142.05 152.60	.025 .100 .175 .300 .525 .700 2.000	do	Vulcan (Special) 4 ft. Stroke—9000 lb. Ram.	20 25 30 35 40 45 52	0.48 0.50 0.32 0.38 0.29 0.26 0.23
71	24 in. Concrete		31.68 68.46 105.47 142.05 172.09	.075 .125 .175 .300 .950	do	do	20 25 30 38	0.34 0.25 0.21 0.35
72	24 in. Concrete		31.68 86.90 142.11 185.08 221.86 234.12 Anchor piles	.000 .075 .125 .200 .425 .625 began to give	do	do	53 56 57	0.111 0.118 0.046
73	14¾ x 9½ in. Pine (Untreated)		31.68 50.07 68.46 80.72 92.98	.100 .250 .325 .450 .550	do	Vulcan No. 1	20 30 40 50 53	1.33 0.57 0.67 0.36 0.23
74	15 x 10 in. Creosoted pine		31.68 50.07 68.46 74.59 80.72	.050 .150 .240 .260 .560	do	do	20 25 30 38	0.92 0.86 0.45 0.43

Pulling Resistance to Start Pile	Type of Structure Supported	Location and Date of Test	General Remarks
	Test pile No. 6	Old B. & B. Yard, Missouri Pacific Ry., Little Rock, Ark. Driven—July 27, 1933 Tested—Aug. 3, 1933	
	Test pile No. 8	do Driven—July 26, 1933 Tested—Aug. 2, 1933	
	Test pile No. 9	do Driven—July 26, 1933 Tested—Aug. 2, 1933	
	Redrive on pile No. 2	do Redriven—Oct. 13, 1933 Tested—Oct. 22, 1933	The points of two piles—Steel Test Report No. 68 and Concrete Report No. 72—were in or above this strata. This accounts for the relatively greater capacity of these two piles as compared to others tested. Capacities of pile which penetrated through strata were less than those stopped in or above. "Driving of piles was fairly easy, and no piles were driven to refusal; in fact, in actual construction work driving resistance would not have been acceptable and longer piles would undoubtedly be used. Test was spread over considerable intervals of time, and the last loadings did not show an appreciable set-up of piles." "It is a fact in driving the steel piles that the material between the outstanding legs was compacted to some extent. The earth core between the legs was driven from 10 to 15 feet below the surface of the pile, or approximately $\frac{1}{4}$ of the depth of the pile. This earth core pulled out with the pile when piles No. 8 and No. 9 were pulled to permit splicing piles No. 2 and No. 3." The results of these tests show that it was of no particular advantage to build up the ends of the piles with an arrangement of angles attached for several feet above the point. An 18 foot section was cut from pile No. 8, after it had been pulled, and the driving of pile No. 2 continued from a previous penetration of 53 feet to a maximum penetration of 60 feet, as shown
	Redrive on pile No. 6	do Redriven—Oct. 13, 1933 Tested—Oct. 20, 1933	After a total test load of 203.47 tons was applied and removed the pile recovered 0.425 inches. After pile No. 9 was pulled an 18 ft. length was cut off and welded to the driven portion of pile No. 6 and driving continued to a penetration of 72 ft. Load was removed after 160.42 tons had been applied, and pile recovered .25 in. At maximum test load of 197.20 tons, anchor pile let go. Test pile was still capable of carrying further load before failure.
	Test pile No. 5	do Driven—July 27, 1933 Tested—Aug. 3, 1933	Pile continued to settle under 172.09 ton load.
	Test pile No. 11	do Driven—July 26, 1933 Tested—Aug. 2, 1933	
	Redrive on pile No. 5	do Redriven—Oct. 13, 1933 Tested—Oct. 30, 1933	
	Test pile No. 3	do Driven—July 27, 1933 Tested—Aug. 3, 1933	
	Test pile No. 12	do Driven—July 26, 1933 Tested—Aug. 2, 1933	

Test Report No.	Kind of Section	Computed or Design Load	Max. Test Load in Tons	Settlement Under Load in Inches	Soil Condition	Kind of Hammer	Penetration in Feet	Penetration Per Blow at End of Driving in Inches
75	24 in. Concrete Pile	132 tons			Fine sand, coarse sand, clay, hard impenetrable shale.	Vulcan No. 0	33	.085 (Av. for 3 piles)
76	18 in. CB 183-71 lb.	104 tons			do	Vulcan No. 1	41	.044 (Av. for 3 piles)
77	do	125 tons			do	do	29	.02 for 1 pile and refusal for 2 piles
78	do	101 tons			do	do	42	.048 (Av. for 3 piles)
79	do	115 tons			do	do	51	.03
80	24 in. Concrete	153 tons			do	Vulcan No. 0	40	.059 (Av. for 5 piles)
81	CB 183-N-71 lb.				30 ft. sand and coarse gravel, 10 ft. shale, firm rock.		42 to 50	Refusal
82	H4-8 x 8-37.7 lb.				Approx. 5 ft. muck, 2 ft. shale, slate.	3000 lb. Gravity	7	
83	IP-24-58.7 lb. Flange-9.45 in. Depth-9.45 in.		33 44 66 77	.078 .098 .256 .475	6.5 ft. sand, 3.0 ft. clayey sand, 14.0 ft. yellow sand, 0.5 ft. hard blue clay, 3.0 ft. clay with sand, 6.5 ft. fine sand.	10850 Ft.-Lbs. Energy	14.6 20.8 29.8 33.5	1.77 1.34 .79 .66
84	IP-24		44 55 66 77 88 99	.079 .098 .138 .187 .217 .474	6.5 ft. sand, 3.0 ft. clayey sand, 14.0 ft. very fine sand, 1.6 ft. blue clay, 0.8 ft. peat, 1.6 ft. blue clay, 6.5 ft. clayey sand, 1.6 ft. sharp sand.	10850 Ft.-Lbs. Energy	7.8 13.8 17.8 21.5 26.0 30.5 35.5	1.97 .71 .79 .47 .55 .51 .63
85	IP-24		44 55 66 77 88 99 110	.059 .075 .079 .099 .118 .150 .177	5.0 ft. sand, 5.0 ft. dirty sand, 14.0 ft. very fine sand, 1.6 ft. blue clay, 1.6 ft. dirty sand, 3.0 ft. sandy clay, 6.0 ft. sharp sand.	do	13.4 20.4 25.4 28.2 31.0 33.3	.75 1.03 .43 .32 .36 .36
86	IP-24		44 55 66 77 88	.098 .158 .177 .236 .591	5.0 ft. fine sand, 6.5 ft. fine dirty sand, 9.5 ft. very fine sand, blue clay.	do	7.4 9.4 11.4 13.1 14.5 17.0 19.5 21.0	1.46 .79 .48 .39 .32 .32 .32 .28
87	IP-24		33 44 55 66 77 88 99 110 121 132 143	.008 .008 .008 .012 .032 .047 .079 .098 .126 .181 .256	6.5 ft. muddy sand, 6.5 ft. gray sand, 6.5 ft. gravel, 8.0 ft. gray sand, 5.0 ft. fine gray sand.	43350 Ft.-Lbs. Energy	8.6 13.2 16.7 22.9 28.3 32.2 33.2	1.97 1.18 .87 .59 .71 .39 .39
88	IP-24		44 55 66 77 88 99 110 121 132	.008 .012 .016 .024 .032 .039 .044 .071 .087	Sand.	43350 Ft.-Lbs. Energy	41.7 46.2 50.0 57.4 64.1 65.6	2.16 1.26 .98 .71 .98 .87
89	8 in. H with plate welded in space between flanges and web, 2 ft. above point	32 tons 44.7 tons 39.7 tons 36.4 tons 39.7 tons 36.4 tons			Sand and gravel.	Vulcan No. 2 do 9-B McKiernan-Terry do do do	36 do do do do do	.125 .063 .037 .050 .037 .050

Pulling Resistance to Start Pile	Type of Structure Supported	Location and Date of Test	General Remarks
	3 Pile Bent No. 1	Missouri Pacific R. R. Co. Bridge No. 239 over Arkansas River, 0.39 miles west of Wichita, Kansas.	Test borings were made which indicated that a firm rock strata would be found at a depth of 49 ft. below base of rail or at a penetration of about 27 ft. at bent No. 11. Piles for bent No. 11 were driven first and from the driving record it will be noted that they drove about as anticipated. This was later found to be typical for bents No. 7 to No. 12, incl., from the driving records. However, for bents No. 13 to No. 16 at the west end of the bridge and bents No. 1 to No. 6 at the east end the rock ledge evidently dropped off rapidly as the penetration per blow increased as well as the actual depth to which piles were driven.
	3 Pile Bent No. 2	do	
	3 Pile Bent No. 11	do	
	3 Pile Bent No. 15	do	Design loads computed by Eng. News Formula.
	6 Pile Bent No. 16	do	Pile Bent No. 16 consisted of 5—24 in. concrete piles and 1—CB-183-71 lb. Behavior of the 2 types can be seen by comparing tests No. 79 and No. 80.
	do	do	
	3 Pile Bents	Missouri Pacific R. R. Co. Bridge No. 528, 1.59 miles east of Nepesta, Colo.	A total of 69 piles were used—23 bents of 3 piles each. On the 12 center bents penetration averaged 42 ft. through approximately 32 ft. sand and gravel and 10 ft. of hard driving through shale to refusal on rock, supposedly. Average penetration for the 11 bents approaching the abutment (6 bents on east end and 5 bents on west end) was 50 ft. under similar driving conditions. Soil conditions were such that sufficient penetration could not be gotten with either wood or concrete piles. Note the satisfactory results with steel piles.
	Concrete Slab Bridge Abutments	Bridge No. ER-6-167, Erie County, Ohio.	A total of 48 piles driven to an average penetration of 7 ft. to slate. The sub-soil was mostly muck, with the exception of the last 2 ft., where an overlying strata of shale was encountered. There was no difficulty at all in keeping piles in position during driving. Information furnished by Mr. H. F. Gerold, Resident Engineer State Highway Dept., Erie County, Ohio.
	Test pile No. 2	Port of Bremen—Germany An article by Dr.—Eng. Agatz, Berlin in "Die Beutechnik" 1934, Heft 5 v. 6 Published by Wilhelm Ernst & Sohn Berlin W 8	
	Test pile No. 14		
	Test pile No. 20		In order to determine the most efficient types of steel piles for use in enlarging some docks, the Port Authority at Bremen, in collaboration with the Dortmunder Union der Vereinigten Stahlwerke, conducted preliminary tests on 27 steel piles, 3 wood piles and 2 concrete piles. Of the steel piles only 3 plain IP-24 sections were driven. They correspond roughly to a CBP 103, 57 lb. section. See test report No. 83.
	Test pile No. 23		The remaining 24 steel test piles all had some form of boxing, angle bands, projecting shelves, etc. The most efficient method consisted of plates about 1/4 in. thick welded on the outer edges of the flanges. The plates were parallel to the webs and spanned from flange to flange. At their lower ends the plates were brought in to the web at an angle of 30° and were welded both to the inner faces of the flange and the web. This formed in effect a rectangular boxed section. When these plates were about 6 to 9 feet long and were attached 15 to 18 feet above the pile point, the highest load capacities with the lowest settlements were obtained. See test report No. 85.
	Pile 1		On basis of data obtained in preliminary tests 4 steel piles as designed for the structure were driven in their final position and tested. These piles had 18 feet of plain section above the point end and then 10 feet of boxed section. Very satisfactory results were obtained. See test reports No. 87 and No. 88.
	Pile III		
	Concrete Arch Bridge Piers and Abutments	Abutment No. 1 Pier No. 1 Pier No. 2 Pier No. 3 Pier No. 4 Abutment No. 2 Sixteenth St. Bridge widening, N. Sacramento, Calif.	One 45 ft. and two 55 ft. test piles were driven. From results of test piles 40 ft. lengths of piles were ordered. All piles were driven to penetration of 36 ft. Formula used in computing design loads for Vulcan Hammer, $P = \frac{2E}{S + 0.1}$ and for McKiernan-Terry Hammer, $P = \frac{1.33E}{S + 0.1}$.

SUSTAINING VALUES FOR VARIOUS SOIL CONDITIONS

The following table shows the maximum test and computed safe or design sustaining value per square foot of net perimeter contact areas of piles for various soils and depth of penetration.

The computed safe or design loads, and the sustaining values, are based on two-thirds of the maximum test loads in cases where settlements were not excessive and where the loads and settlements were proportionate and their curve remained a straight line. Where test loads were carried to failure, the safe or design loads are based on two-thirds of the greatest loads at which settlements were not excessive and at which loads and settlements were proportionate. Safe loads taken at two-thirds of these limits may be used in bearing pile designs, for they represent values for piles which can safely sustain 150% of their design loads without excessive settlement.

It will be noted that the groupings indicate the soil conditions, size of pile, and depth of penetration, which are all important factors in determining the sustaining values.

Test	Kind of Section	Net Perim. Ft.	Penetration in Feet	Contact Surface Sq. Ft.	Test Values		Ultimate Values at Failure	Computed, Safe or Design Value	
					Load in Pounds	Lbs. per Sq. Ft.		Load in Pounds	Lbs. per Sq. Ft.
SAND AND GRAVEL									
Mackinaw Bridge, Elkhorn River, Neb. No. 8	8″ H-32 lb.	2.67	30	80.0	Pulling 235,600	2,940		120,000	1,500
Gothenburg Br., Neb. No. 9	8″ H-32 lb.	2.67	43	115.0	340,000	2,960		226,000 140,000	1,970 * 1,220★
Fairbury, Neb. No. 11	8″ H	2.67	19.5	52.0	162,000	3,110		108,000	2,080*
do No. 12	10″ H	3.33	14.2	47.2	138,000	2,930		92,000	1,950 *
do No. 13	10″ H	do	14	46.6	216,000	4,630		144,000	3,090 *§
Pender, Neb. No. 15	8″ H-32 lb.	2.67	26	69.5	70,000	1,010		47,000	680*
Wood River, Neb. No. 17	8″ H-32 lb.	2.67	38	101.5	56,000	550		37,700	372*†
Clarks Bridge, Columbus, Neb. No. 18	10″ H do do do do	3.33 do do do do	20 32 37 45 52	66.6 106.4 123.0 150.0 173.0				20,000 40,000 50,000 60,000 70,000	300 † 375 † 407 † 400 † 404 †
Gary A. B. Co. No. 28	12″ CB-110 lb. 60° point	4.02	35	141.0	450,000	3,190	300 T 4250	300,000	2,124
do No. 29	do	4.02	45	180.5	400,000	2,220	307 T 3400	268,000	1,480
Santa Clara River, Montalvo, Cal. No. 33	10″ H-49.5 lb.	3.33	40	133.2	120,000	900		80,000	602
Leeper, No. 47	10″ CB-49 lb.	3.33	63	210.0				134,000	638
do No. 48	do	do	32	106.8				134,000	1,258 ‡
do No. 49	do	do	25	83.3				134,000	1,610 ‡
do No. 50	do	do	25	83.3				138,000	1,658 ‡
do No. 51	do	do	38	126.8				138,000	1,090
do No. 52	do	do	44	146.5				134,000	916
do No. 53	do	do	51	170.0				134,000	786
do No. 54	do	do	41	136.8				134,000	980
do No. 55	do	do	19	63.3				138,000	2,180 ‡
do No. 56	do	do	66	220.0				134,000	610
do No. 57	do	do	26	86.6				134,000	1,548 ‡
do No. 58	do	do	31	103.2				134,000	1,298 ‡
do No. 59	do	do	29	96.6				134,000	1,388 ‡
Black River Br. No. 43	do	do	45	150.0				134,000	893
do No. 44	do	do	48	160.0				134,000	840
do No. 45	do	do	43	143.2				132,000	922
do No. 46	do	do	44	146.5				130,000	886
Sacramento, No. 89	8″ H with plates between flanges and web 2′ above point	2.67 do do do	36 do do do	96.0 do do do				64,000 89,400 79,400 72,800	667 930 828 748
CLAY, LOOSE GRAVEL, HARDPAN									
Miami River, No. 42	10″ CB-49 lb.	3.33	34	113.2				129,000 ⊙	1,140

* 2/3 of test without settlement.
† Soil probably mixed with clay, loam and silt.
‡ Piles probably driven to hardpan.
★ Limited by steel at 15,000 lb. per sq. in.
§ Probably cemented sand and gravel.
⊙ Computed by formula $P = \frac{2\,WH}{S + 0.1}$

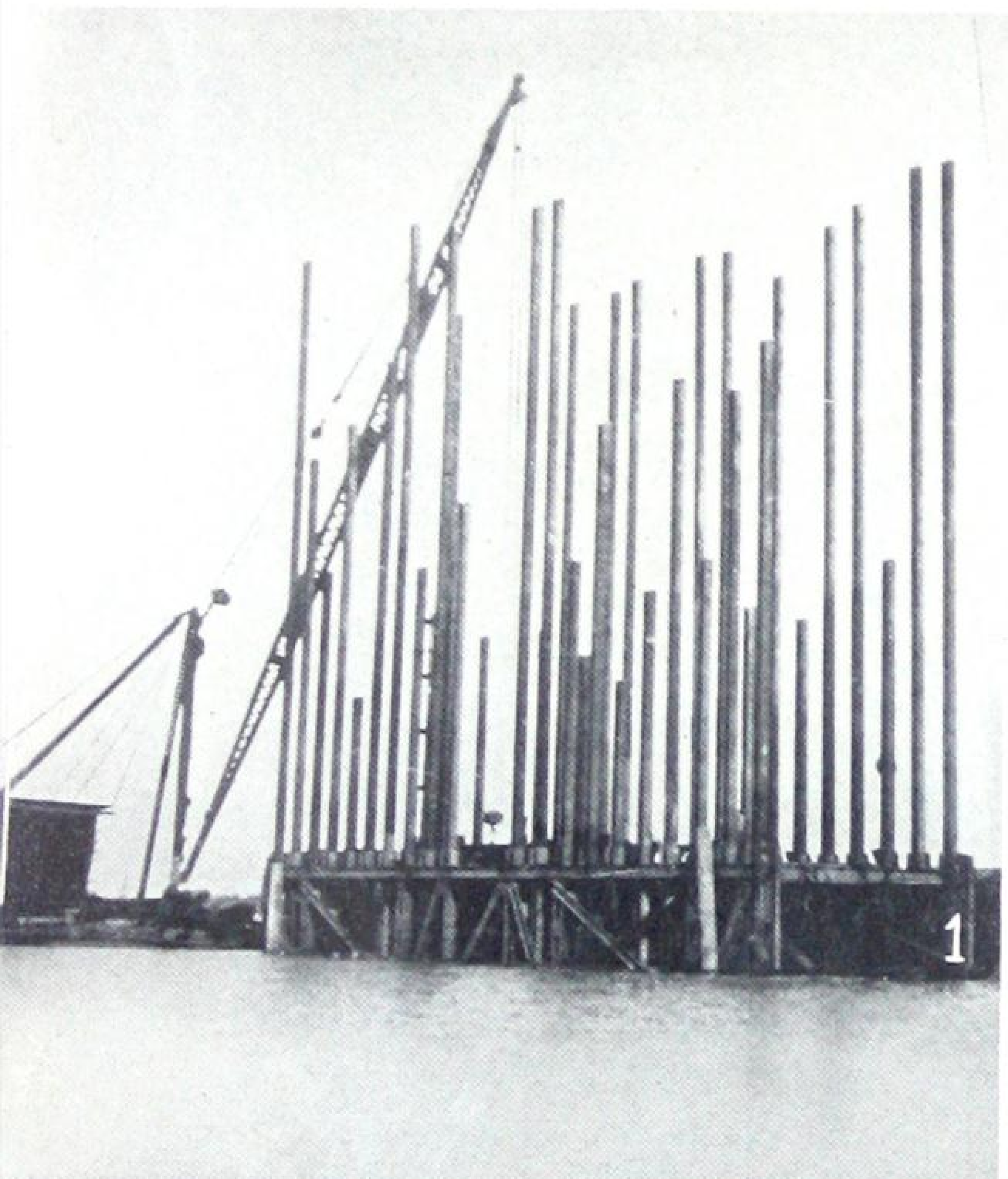
SUSTAINING VALUES FOR VARIOUS SOIL CONDITIONS

Test	Kind of Section	Net Perim. Ft.	Penetration in Feet	Contact Surface Sq. Ft.	Test Values: Load in Pounds	Test Values: Lbs. per Sq. Ft.	Ultimate Values at Failure	Computed, Safe or Design Value: Load in Pounds	Computed, Safe or Design Value: Lbs. per Sq. Ft.
GRAVEL									
Miami River, No. 39	10″ CB-49 lb.	3.33	40	133.3				92,000 ⊙	688
do No. 40	do	do	24	80.0				89,200 ⊙	1,115
do No. 41	do	do	34	113.2				76,000 ⊙	672
DRY GRAVEL AND CLAY									
Beth. Steel Co. Pacific Coast, No. 26	8″ H-32 lb.	2.67	36	96.1	120,000 No settlement	1,250	2/3	80,000 *	832
do No. 27	8″ H-32 lb.	2.67	38	101.5				60,000	590
Miami River Br. No. 37	10″ CB-49 lb.	3.33	30	100.0				145,000 ⊙	1,450
do No. 38	do	3.33	24	80.0				92,000 ⊙	1,150
SAND									
Worcester, Mass. No. 34	8″ H-31 lb.	2.67	56.5	151	130,000	860		90,000	597
Port of Bremen No. 87	IP-24 Wt. 58.7 lb. Depth 9.45″ Flange 9.45″ Boxed for 10′ 0″ beginning 18′ 0″ above point	3.14	33.2	104	286,000	2,750		162,000	1,556
do No. 88	do	3.14	65.6	206	264,000	1,280		147,200	715
SAND AND CLAY									
Monroe, La., No. 60	8″ CB-33 lb.	2.67	48.5	129.5	68,000	525	617 lbs. per sq. ft. at 40 T	50,000	385
do No. 63	do	do	49.5	132.0	90,000	681	741 lbs. per sq. ft. at 49 T	60,000	455
Mo. Pac. Ry. Little Rock, No. 64	14″ CB-95 lb.	4.75	53.0	252.0	173,700	690		90,000	360
do No. 65	16″ CB-83 lb. With LS	4.60	53.0	244.0	149,180	612		100,000	410
do No. 66	14″ CB-95 lb.	4.75	38.0	180.5	148,000	820		90,000	500
do No. 67	16″ CB-83 lb.	4.60	38.0	175.0	146,940	840	840 lbs. per sq. ft. at 73.47 T	90,000	525
do No. 68	14″ CB-95 lb.	4.75	60.0	285.0	406,940	1,430		270,000	944
do No. 69	16″ CB-83 lb.	4.60	72.0	331.0	394,400	1,195		270,000	815
Mo. Pac. Ry. Br. Wichita, No. 76	18″ CB-183-71 lb.	5.82	41.0	239.0				208,000	872
do No. 77	do	5.82	29.0	169.0				250,000	1,480
do No. 78	do	5.82	42.0	244.5				202,000	826
do No. 79	do	5.82	51.0	297.0				230,000	775
Port of Bremen No. 83	IP-24 Wt. 58.7 lb. Depth 9.45″ Flange 9.45″	3.14	33.5	105.0	154,000	1,465		59,000	561
do No. 84	do Boxed for 13′ beginning 3′ 3″ above point	3.14	35.5	111.0	198,000	1,785		74,000	666
do No. 85	do Boxed for 6′ 0″ beginning 19′ 9″ above point	3.14	33.3	104.5	220,000	2,100		118,000	1,128
6′ TO 9′ CINDER AND SAND • 12′ TO 20′ SWAMP MUD • 15′ TO 22′ SOFT CLAY AND SAND • 9′ TO 16′ STIFF RED CLAY									
Passaic River Br. No. 19	12″ H-65.5 lb.	4.02	Av. 52.5	210.5	104,000 121,000	494 575		86,000	408

* ⅔ of test without settlement. ⊙ Computed by formula $P = \frac{2\,WH}{S + 0.1}$

SUSTAINING VALUES FOR VARIOUS SOIL CONDITIONS

Test	Kind of Section	Net Perim. Ft.	Pene-tration in Feet	Contact Surface Sq. Ft.	Test Values		Ultimate Values at Failure	Computed, Safe or Design Value	
					Load in Pounds	Lbs. per Sq. Ft.		Load in Pounds	Lbs. per Sq. Ft.
15′ NEW FILL SAND AND SILT • 10′ MUD, One month after completion of hydraulic fill in tide flats • 100′ SAND (Penetrations given are 10′ less than actual. Thickness of mud layer deducted.)									
Beth. Steel Co. Seattle No. 21	8″ H-32 lb.	2.67	50	133.5	200,000	1,495		134,000	1,000
	do		55	146.8	120,000	819		80,000	545
	do		40	107.0	160,000	1,495		107,000	1,000
do No. 20	10″ G-41.5 lb.	3.17	30	95.2	80,000	840		53,000	557
	do		45	142.8	150,000	1,050		100,000	700
	do		55	174.5	200,000	1,148		134,000	768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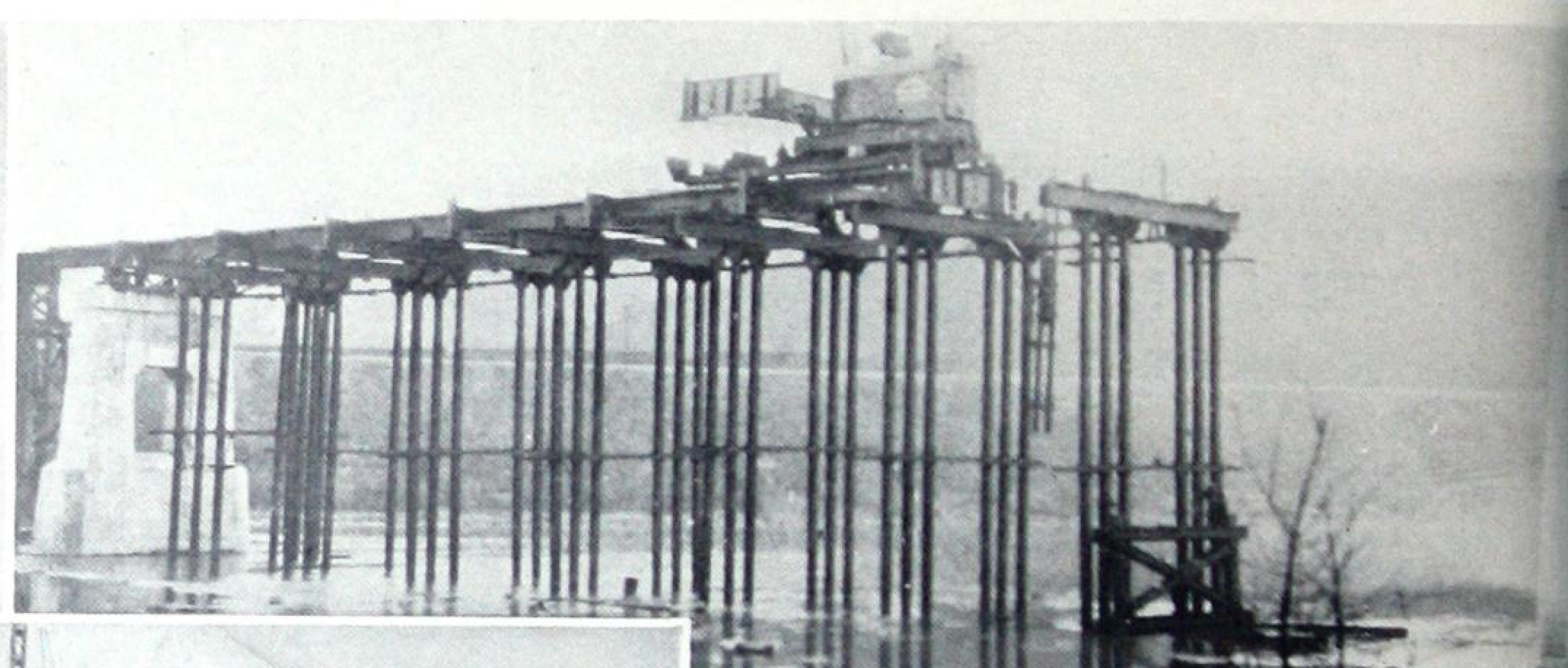

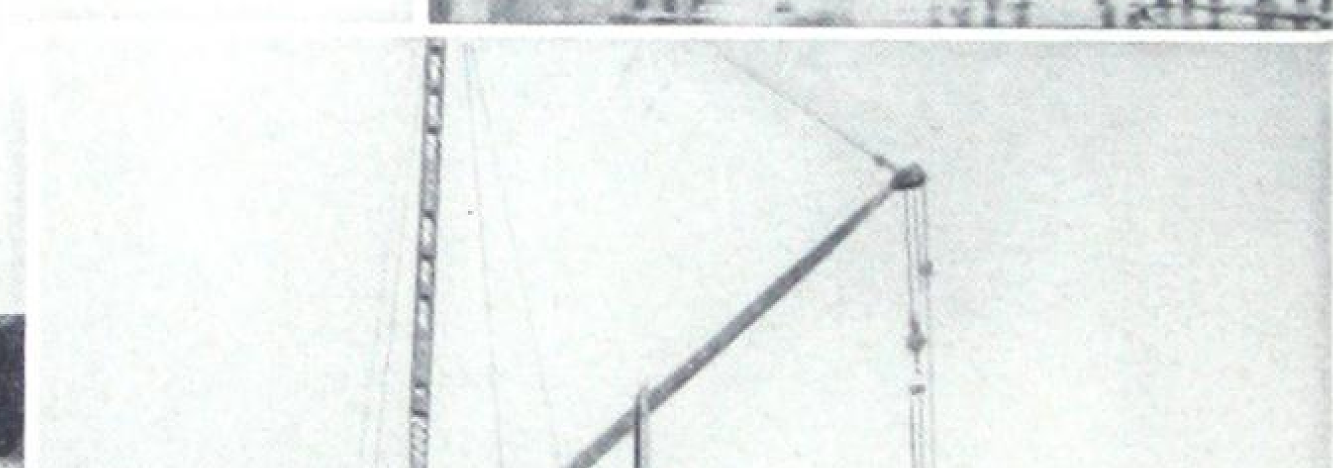
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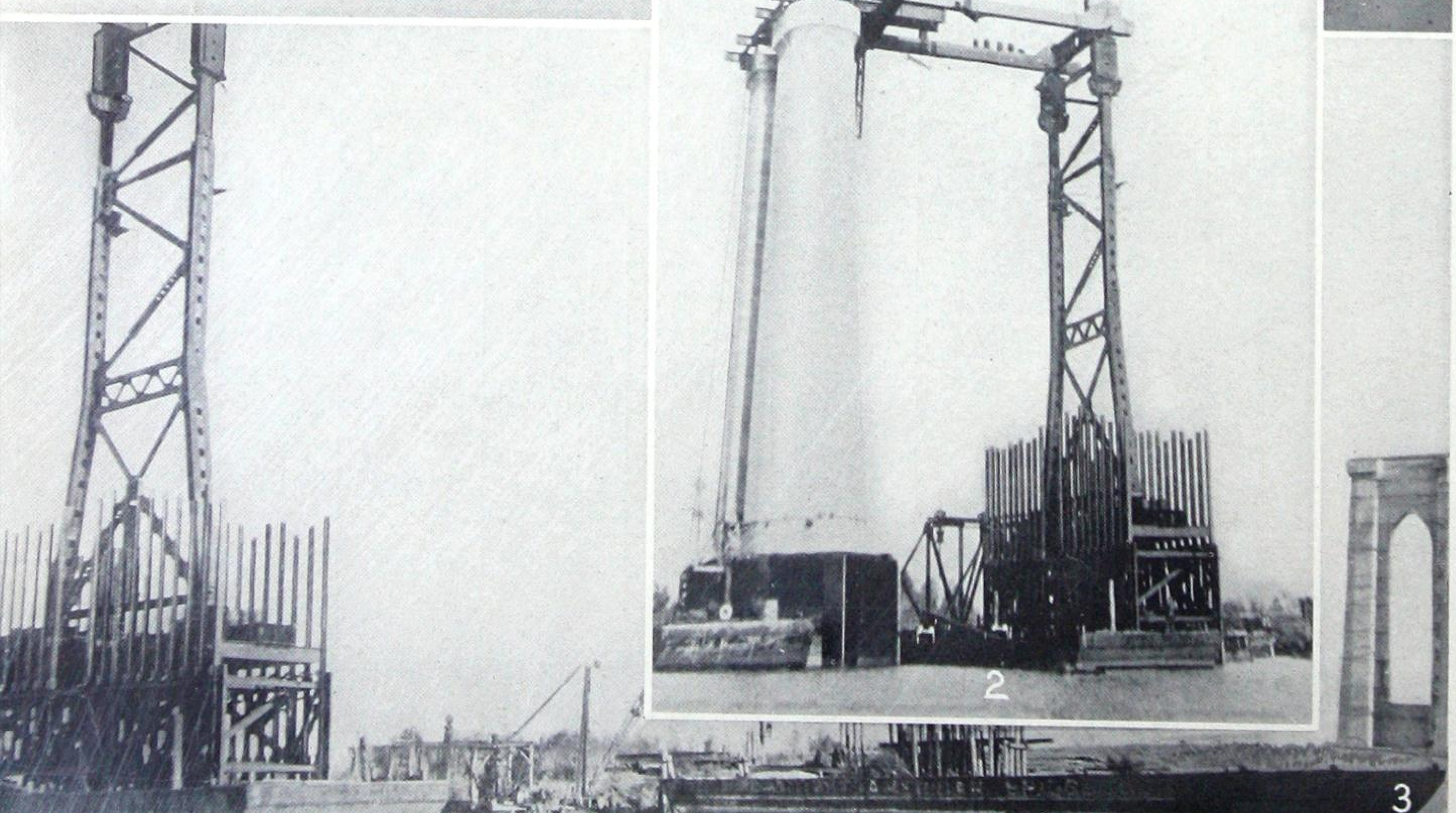
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BRIDGE OVER
YOUGHIOGHENY RIVER
Pittsburgh & West Va. Ry. Co.

•

4. STEEL FALSEWORK PILES USED IN ERECTION.

H. H. TEMPLE, CHIEF ENGINEER
FABRICATED AND ERECTED BY AMERICAN BRIDGE COMPANY

•

MISSISSIPPI RIVER BRIDGE
AT NEW ORLEANS

12″ CB 120 LB. SECTIONS. INDIVIDUAL PILES 175′ LONG MADE UP OF 3 LENGTHS WITH FULL BOLTED SPLICES.

1. PLACING FALSEWORK PILES IN GUIDE CAGE.

•

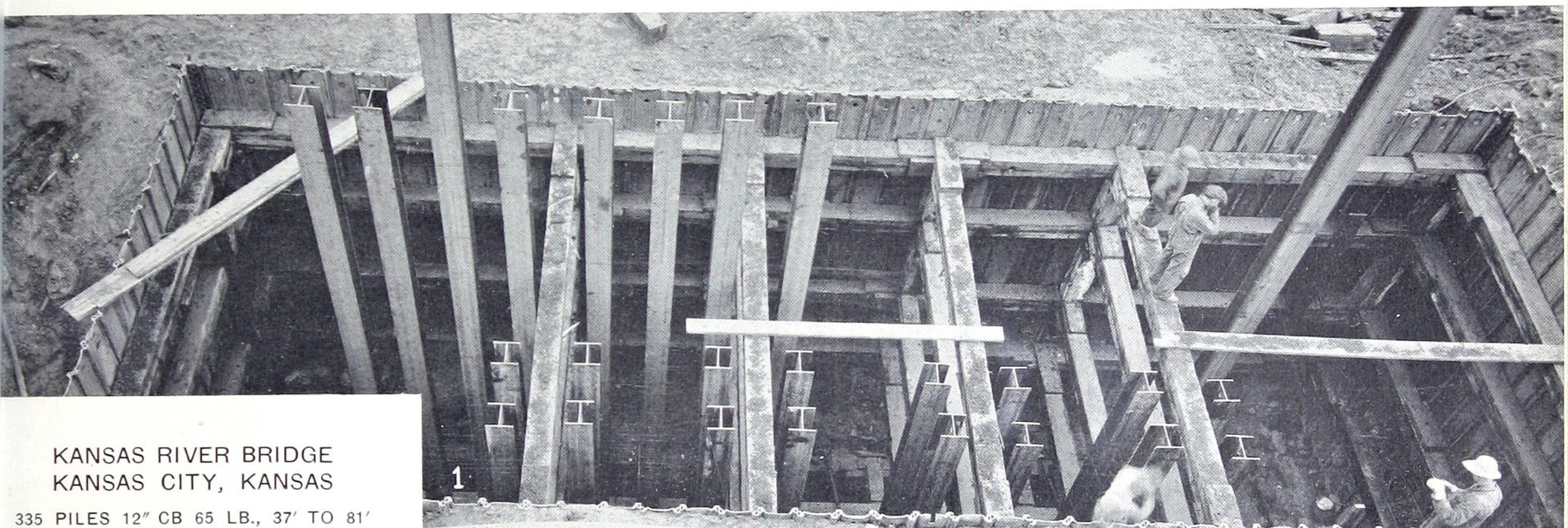
2 AND 3. FALSEWORK PILE GROUP AND BRACING CAGE SUPPORTING TEMPORARY ERECTION TOWER.

•

MODJESKI, MASTERS & CASE, ENGINEERS
AMERICAN BRIDGE COMPANY, FABRICATORS AND ERECTORS

SUSTAINING VALUES FOR VARIOUS SOIL CONDITIONS

Test	Kind of Section	Net Perim. Ft.	Pene-tration in Feet	Contact Surface Sq. Ft.	Test Values		Ultimate Values at Failure	Computed, Safe or Design Value	
					Load in Pounds	Lbs. per Sq. Ft.		Load in Pounds	Lbs. per Sq. Ft.
CLAY • SANDY CLAY • HUMUS AND CLAY • SAND, SHELLS AND CLAY • STIFF BLUE CLAY									
Bonnet Carre No. 2	10″ CB-49 lb. Bottom pointed	3.33	89.0	296.5	98,000	331		66,000	223
do No. 3	10 CB-49 lb. Boxed—Sq. Pyramid point	3.33	89.0	296.5	122 400	413		80 000	270
do No. 4	12″ CB-65 lb.	4.02	122.0	490.4	220,000	448		148,000	302



1

KANSAS RIVER BRIDGE
KANSAS CITY, KANSAS

335 PILES 12″ CB 65 LB., 37′ TO 81′ LONG, DRIVEN INTO HEAVY SHALE TO RESISTANCE OF AT LEAST 25 BLOWS PER INCH OF PENETRATION. VULCAN HAMMER NO. 1 USED.

DIRECT VERTICAL LOAD PER PILE 35 TONS. COMBINED DESIGN LOADS EXCEED 50 TONS WHEN ALL LATERAL FORCES ARE CONSIDERED ACTING IN COMBINATION WITH VERTICAL LOADS.

•

1. TOP VIEW OF PIER NO. 8. SOME PILES PARTIALLY DRIVEN; OTHERS BEING PLACED. LOWER PORTION OF EXCAVATION PROTECTED BY PILING AT NEAT SIZE OF PIER. PART OF SPACING FRAMEWORK IS VISIBLE. UPPER PORTION OF CELL IS FOUR OR FIVE FEET OUTSIDE THE WALLS OF LOWER PART. CARNEGIE STEEL SHEET PILING M-107 THROUGHOUT.
2. WORKMEN PLACING PILE IN SPACING FRAME. SOME PILES ARE PARTIALLY DRIVEN; OTHERS DOWN TO REFUSAL READY FOR CUTTING OFF AND CAPPING.

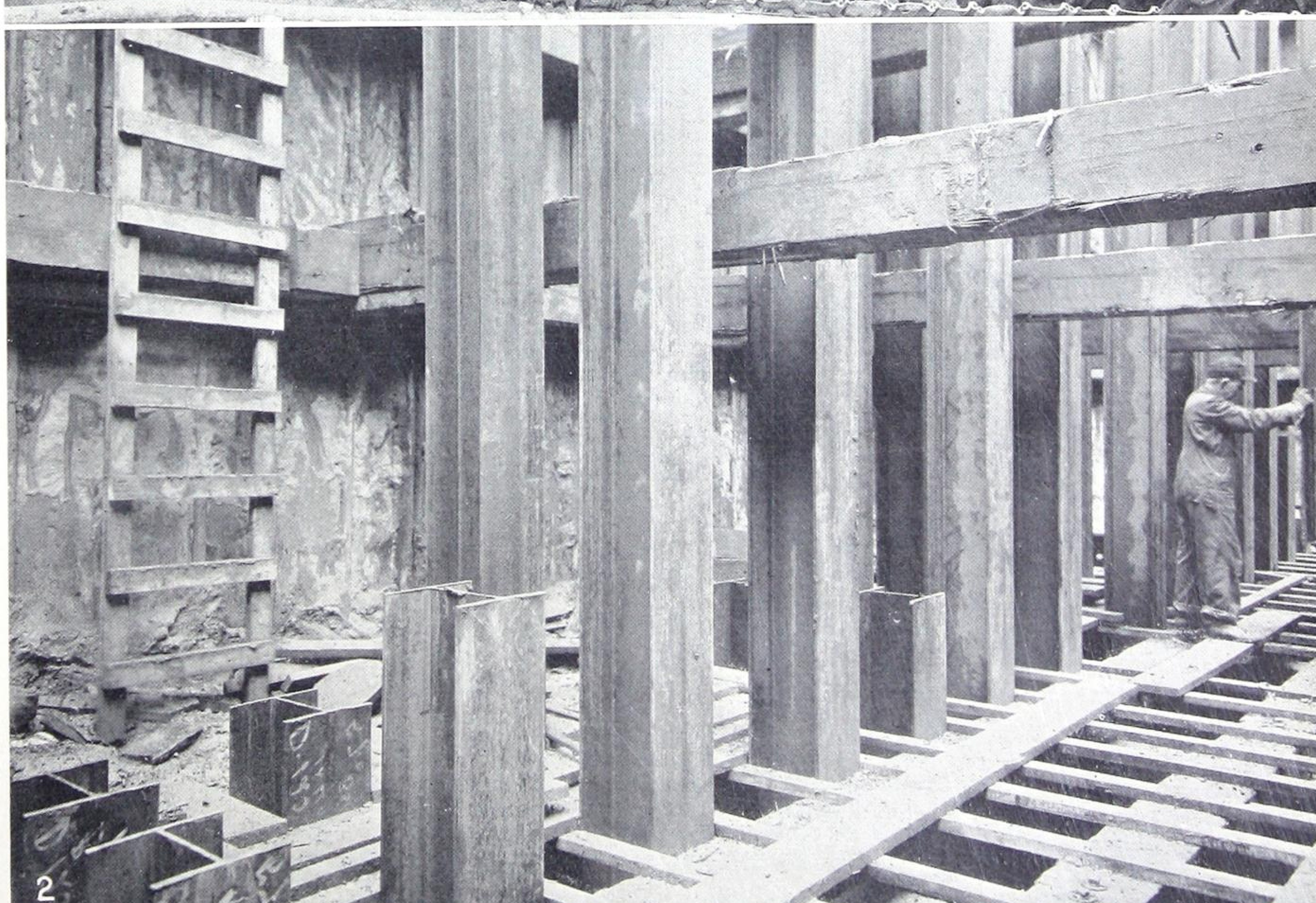
•

DESIGNED BY SVERDRUP AND PARCEL, CONSULTING ENGINEERS, ST. LOUIS

KANSAS CITY BRIDGE CO., GENERAL CONTRACTORS

KANSAS CITY STRUCTURAL STEEL COMPANY
STRUCTURAL STEEL FABRICATORS

SEE ENGINEERING NEWS-RECORD ARTICLE OF OCT. 19, 1933, FOR COMPLETE DETAILS.



2

• BEARING VALUES OF CBP PILES • FOR VARIOUS LENGTHS • IN REPRESENTATIVE GROUPS OF SOILS

On the basis of the average safe or design sustaining values given in preceding tables as determined from tests, reasonable prediction of the bearing values of various sizes and lengths of CBP bearing piles are given in the following tabulation. These values should be used only for preliminary or tentative designs subject to final determination of actual length of piles by test. Where the piles show considerable resistance to driving, driving formulae as given herein may be considered as giving conservative values. Where the driving is relatively easy, the capacities of piles should be checked by load tests.

RECOMMENDED MAXIMUM LOADS AND APPROXIMATE AVERAGE DEPTHS OF PENETRATION REQUIRED FOR THEIR DEVELOPMENT

Actual test piles driven at site may indicate variations in required depth of penetration with minimum and maximum lengths varying in same ratios as minimum and maximum sustaining values

Driving and Soil Conditions	Unit Stress in Steel, Lbs. per Sq. In.	Sustaining Values, Lbs. per Sq. Ft. Based on Net Perimeter			BEARING PILE SECTIONS								
					N. P. = 5.0′ 14″ x 16″ CBP 146		N. P. = 4.75′ 14″ x 14½″ CBP 145		N. P. = 4.00′ 12″ x 12″ CBP 124		N. P. = 3.33′ 10″ x 10″ CBP 103		N. P. = 2.67′ 8″ x 8″ CBP 83
*Piles driven to—		Min.	Max.	Normal Average	117 lb.	102 lb.	89 lb.	73 lb.	74 lb.	53 lb.	57 lb.	42 lb.	36 lb.
					Maximum Loads in Tons. Depths of Penetration in Feet								
Refusal, in rock, shale, cemented sand and gravel, or hardpan	10,000	Piles act as columns			172 T.	150 T.	130 T.	107 T.	109 T.	78 T.	84 T.	62 T.	53 T.
					Depth of penetration dependent on length required to reach hard supporting strata.								
Practical refusal, in sand and gravel	8,000	602	1658	1033 (24 Tests)	136 T. 53 Ft.	120 T. 47 Ft.	104 T. 43 Ft.	86 T. 35 Ft.	87 T. 42 Ft.	62 T. 30 Ft.	67 T. 39 Ft.	49 T. 29 Ft.	42 T. 30 Ft.
Practical refusal, in gravel	8,000	590	1450	955 (8 Tests)	136 T. 57 Ft.	120 T. 50 Ft.	104 T. 46 Ft.	86 T. 38 Ft.	87 T. 46 Ft.	62 T. 33 Ft.	67 T. 43 Ft.	49 T. 31 Ft.	42 T. 33 Ft.
Practical refusal, in sand	8,000	545	1000	735 (8 Tests)	136 T. 74 Ft.	120 T. 65 Ft.	104 T. 60 Ft.	86 T. 49 Ft.	87 T. 59 Ft.	62 T. 42 Ft.	67 T. 55 Ft.	49 T. 40 Ft.	42 T. 43 Ft.
High resistance, in hard, sandy clays	6,000	360	944	623 (13 Tests)	102 T. 65 Ft.	90 T. 58 Ft.	78 T. 53 Ft.	65 T. 44 Ft.	65 T. 52 Ft.	46 T. 37 Ft.	50 T. 48 Ft.	37 T. 36 Ft.	32 T. 38 Ft.
Medium resistance, in hard clays	6,000	360	525	438 (7 Tests)	102 T. 93 Ft.	90 T. 82 Ft.	78 T. 75 Ft.	65 T. 63 Ft.	65 T. 74 Ft.	46 T. 53 Ft.	50 T. 69 Ft.	37 T. 51 Ft.	32 T. 55 Ft.
Low resistance, in layers of sand, medium clay and silt	4,000	223	302	265 (3 Tests)	68 T. 103 Ft.	60 T. 91 Ft.	52 T. 83 Ft.	43 T. 68 Ft.	43 T. 81 Ft.	31 T. 59 Ft.	33 T. 75 Ft.	25 T. 57 Ft.	21 T. 60 Ft.
Low resistance, in soft clay or silt	The use of plain sections, as rolled, is not recommended. (Tests at site may indicate that satisfactory results can be obtained by using piles with devices attached for increasing the bearing values.)												

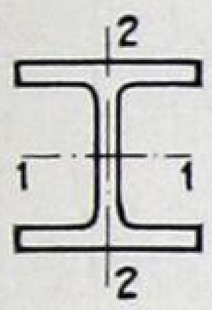
***Definition of Driving Terms**

Refusal	— .00 to .10 inch per blow	with hammer delivering energy of at least 15,000 ft.-lbs. per blow.
Practical Refusal	— .10 to .25 " " "	
High Resistance	— .25 to .50 " " "	
Medium Resistance	— .60 to 1.00 " " "	
Low Resistance	—1.25 to 1.75 " " "	

N. P., the net perimeter, is indicated by dash line.

Notes:

1. Depths of penetration given above are computed using Normal Average Sustaining Values.
2. All the above values based on test results or driving data from driving plain steel sections as rolled. Values obtained for piles with various attachments for increasing resistance or capacity not included.
3. High l/r ratios may require reduction in steel unit stresses.
4. Approximate data for other sections may be obtained by interpolation or by computation after selecting proper values and units.
5. Penetration in Feet = Load ÷ (Sustaining Value per Sq. Ft. x Net Perimeter in Feet).



BEARING PILES

ELEMENTS OF CBP AND CB SECTIONS

Section Index	Nominal Size	Depth of Section	Weight per Foot	Area of Section	Flange Width	Flange Thickness	Web Thickness	Axis 1-1 I	Axis 1-1 S	Axis 1-1 r	Axis 2-2 I	Axis 2-2 S	Axis 2-2 r
	In.	In.	Lbs.	In.^{2}	In.	In.	In.	In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.
CBP 146	14 x 16	14.18	117	34.42	15.599	.778	.779	1233.5	174.0	5.99	492.8	63.2	3.78
		13.99	102	30.00	15.500	.681	.680	1060.9	151.7	5.95	423.1	54.6	3.75
CBP 145	14 x 14½	13.86	89	26.19	14.696	.616	.616	909.1	131.2	5.89	326.2	44.4	3.53
		13.70	73	21.46	14.518	.538	.438	762.2	111.3	5.96	274.5	37.8	3.58
CBP 124	12 x 12	12.12	74	21.76	12.217	.607	.607	566.5	93.5	5.10	184.7	30.2	2.91
CB 124		12.12	65	19.11	12.000	.606	.390	533.4	88.0	5.28	174.6	29.1	3.02
CBP 124		11.78	53	15.59	12.046	.437	.436	394.8	67.0	5.03	127.4	21.2	2.86
CBP 103	10 x 10	10.01	57	16.76	10.224	.564	.564	294.7	58.9	4.19	100.6	19.7	2.45
CB 103		10.00	49	14.40	10.000	.558	.340	272.9	54.6	4.35	93.0	18.6	2.54
CBP 103		9.72	42	12.35	10.078	.418	.418	210.8	43.4	4.13	71.4	14.2	2.40
CBP 83	8 x 8	8.03	36	10.60	8.158	.446	.446	119.8	29.9	3.36	40.4	9.9	1.95
CB 83		8.06	33	9.70	8.012	.463	.300	117.9	29.3	3.49	39.7	9.9	2.02

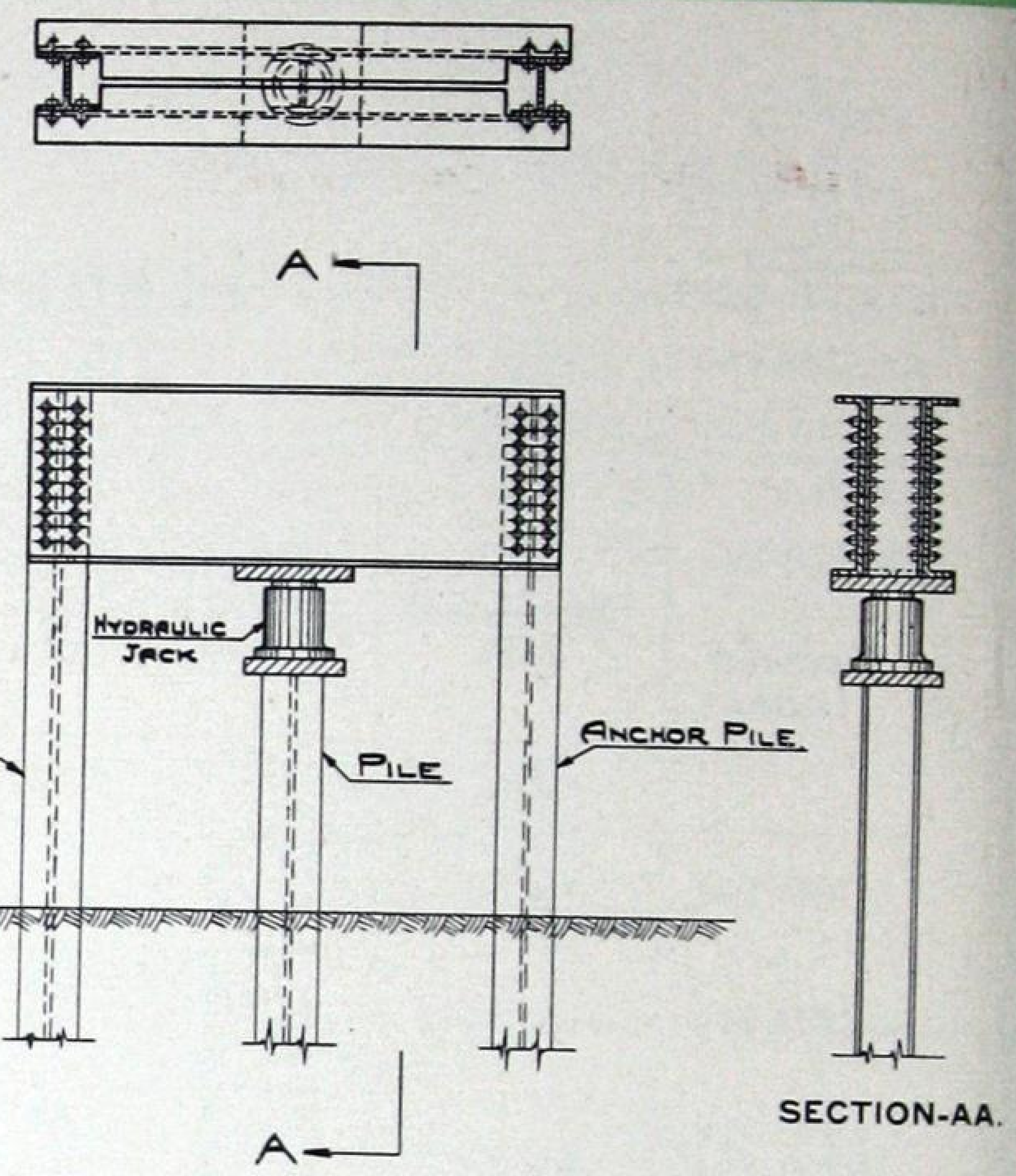
COLUMN LOADS IN KIPS FOR CBP AND CB SECTIONS

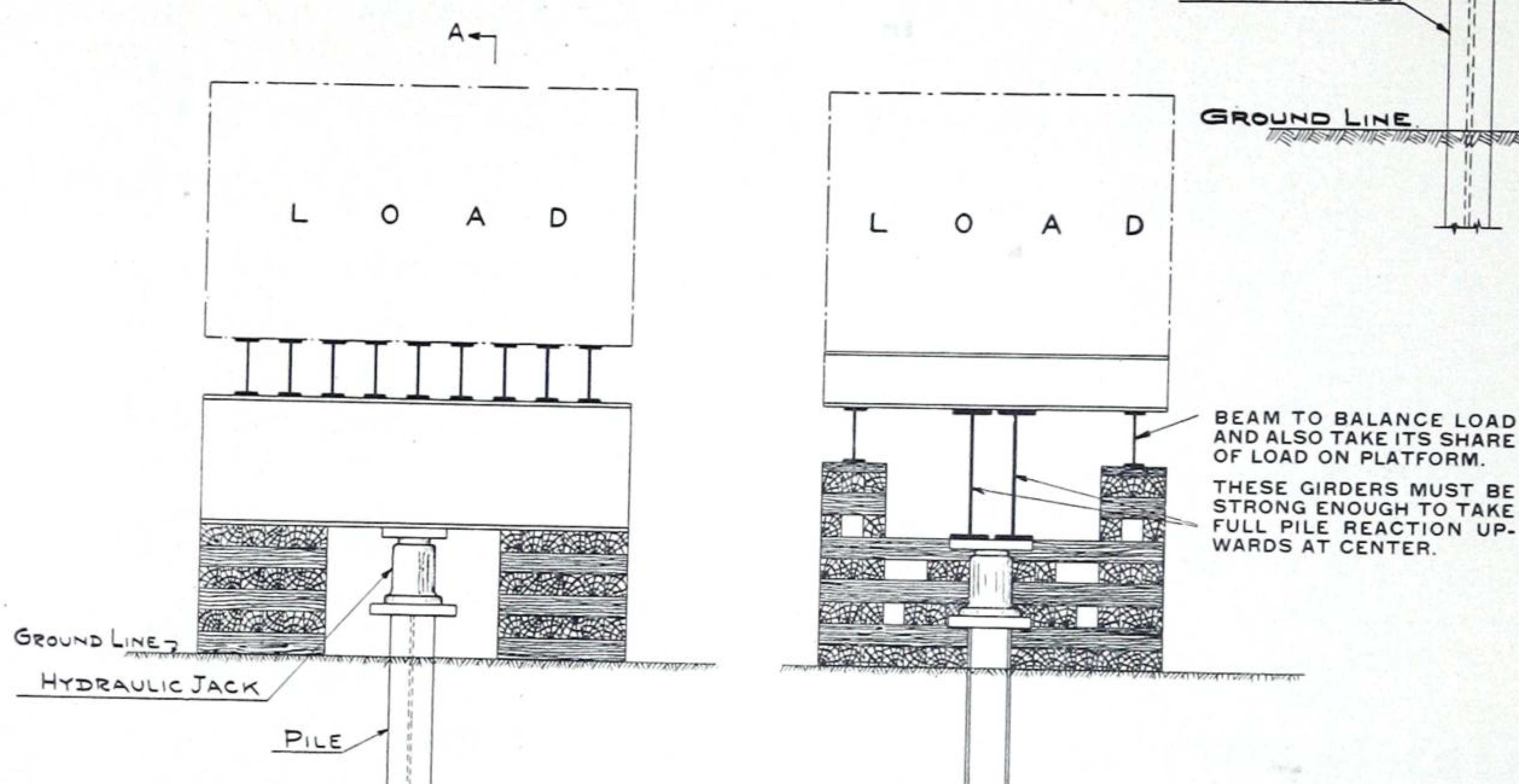
Effective Length in Feet	CBP 146 117 Lbs.	CBP 146 102 Lbs.	CBP 145 89 Lbs.	CBP 145 73 Lbs.	CBP 124 74 Lbs.	CB 124 65 Lbs.	CBP 124 53 Lbs.	CBP 103 57 Lbs.	CB 103 49 Lbs.	CBP 103 42 Lbs.	CBP 83 36 Lbs.	CB 83 33 Lbs.
14					326	287	234	239	209	175	135	126
16			393	322	315	281	224	225	197	164	124	116
18	516	450	390	321	300	268	213	211	185	153	113	107
20	506	440	375	309	284	255	202	197	173	143	104	98
22	488	423	360	297	269	242	190	183	162	133	95	90
24	468	407	344	284	253	228	180	171	151	124	86	82
26	450	390	329	272	239	216	169	159	141	115	79	75
28	431	373	314	259	225	204	159	148	131	106	72	69
30	412	357	299	247	212	192	149	137	123	99	66	63
32	394	341	284	236	199	181	140	128	114	92	60	58
34	376	326	271	224	187	171	132	119	107	85		
36	359	311	257	213	176	161	124	111	99	79		
38	343	296	245	203	166	152	116	103	93	74		
40	327	283	233	193	156	143	109	96	87	69		
42	312	270	221	184	147	135	103		81			
44	297	257	210	175	139	127	97					
46	284	245	200	166	131	120	91					
48	271	234	190	158	123	114						
50	258	223	181	151		108						
52	246	213	172	144								
54	235	203	164	137								
56	225	194	156	131								
58	215	185	149	125								
60	205	177										

Safe load values above upper zig-zag line are for ratios of l/r not over 60, those between zig-zag lines are for ratios up to 120 and those below lower zig-zag line are for ratios not over 200.

A—LOADING PRODUCED BY JACKING AGAINST

GIRDERS ATTACHED TO ANCHOR PILES.

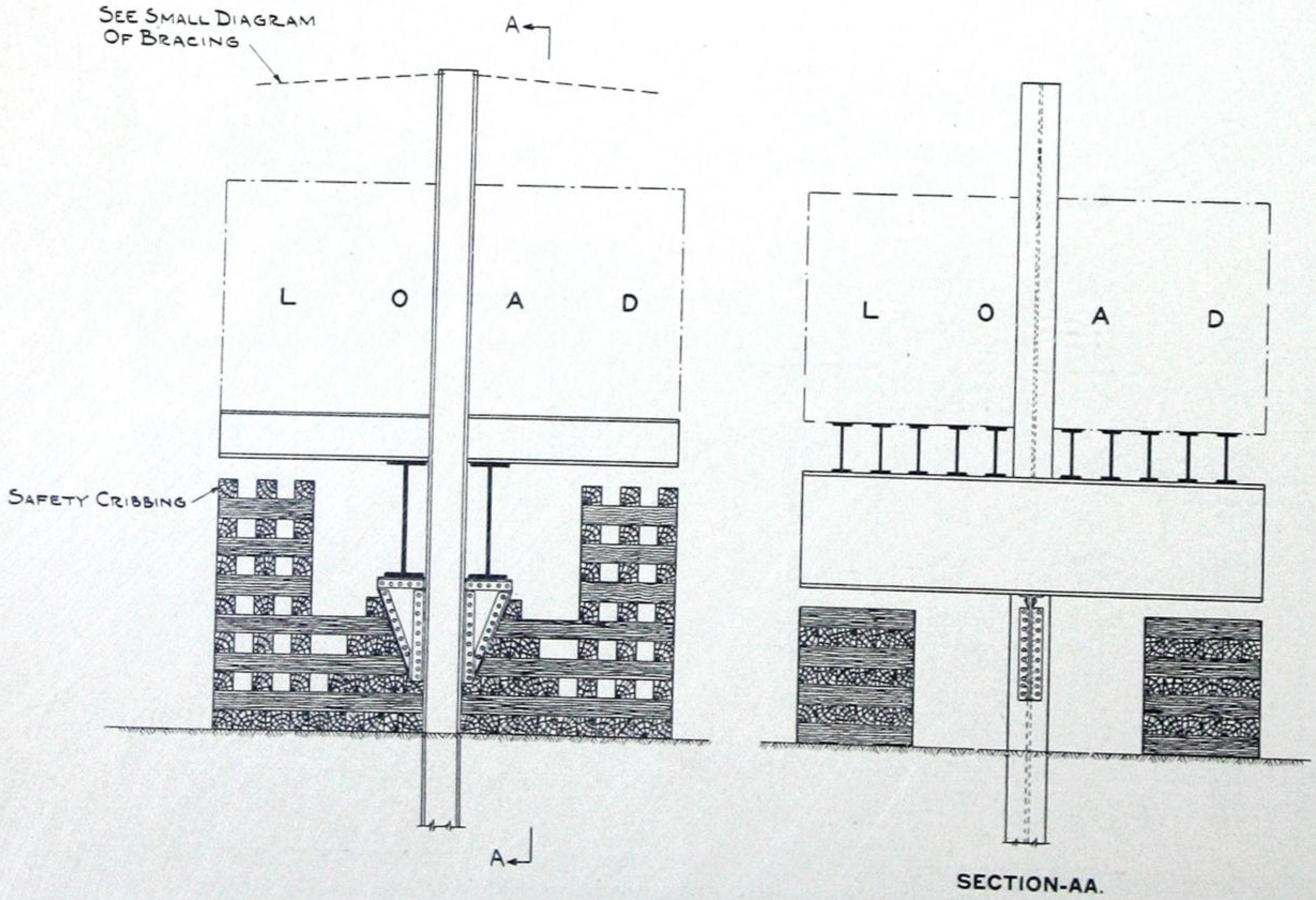




A SECTION-AA.

B—LOADING PRODUCED BY JACKING AGAINST

GIRDERS UNDER LOAD OF KNOWN WEIGHT



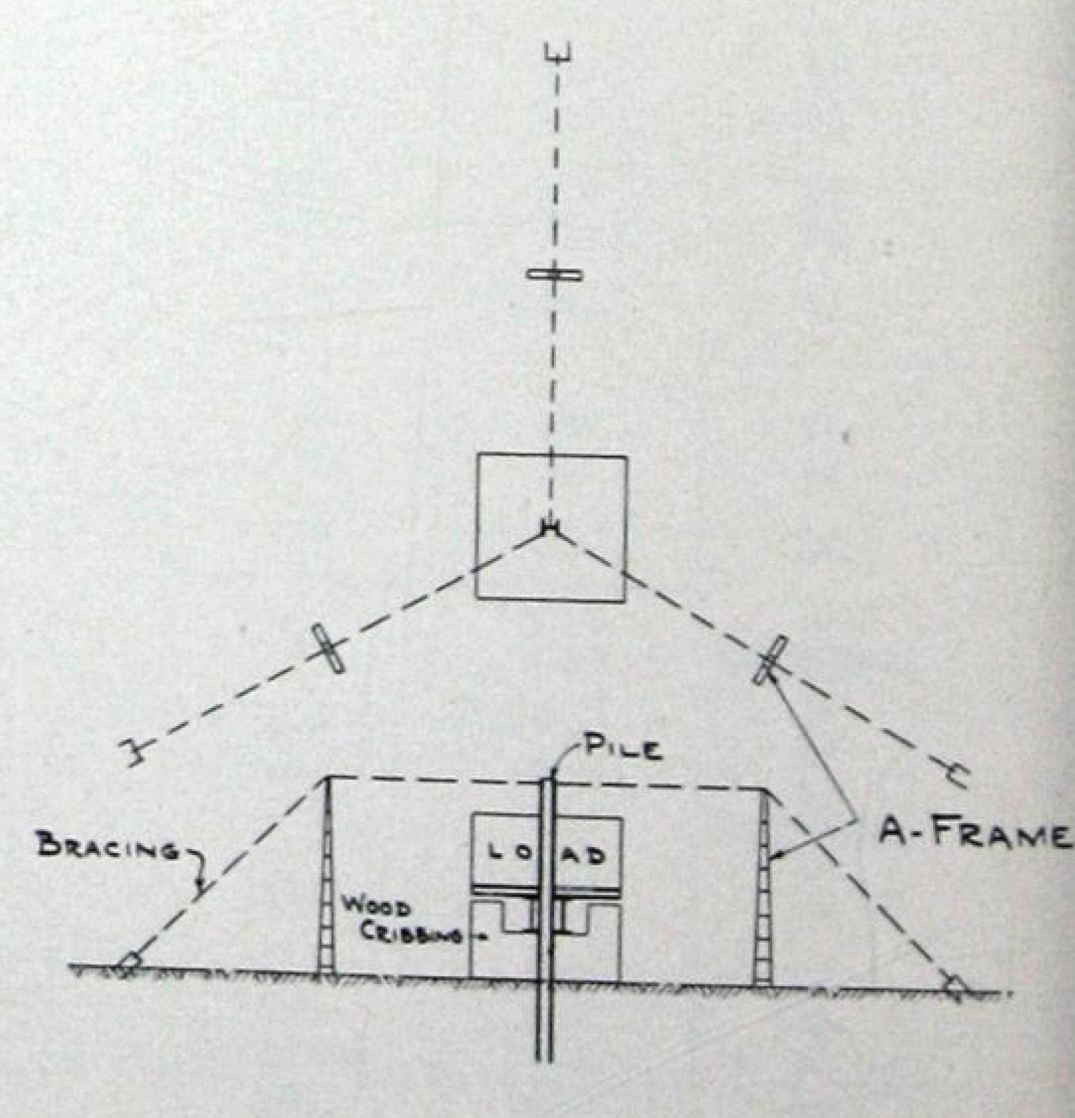


DIAGRAM SHOWING BRACING

C—LOADING PRODUCED BY DIRECT APPLICATION OF WEIGHTS ON PLATFORM ATTACHED TO PILE.

TESTS OF BEARING CAPACITY OF PILES

Tests are usually made with 150 to 200% of the proposed load. They are generally considered satisfactory and the results acceptable if after standing from 24 to 48 hours without settlement the total net settlement, after deducting rebound or elastic recovery of the pile itself, is not more than 0.005 to 0.01" per ton of total test load.

It is recommended that, wherever possible, tests be made on groups of at least three piles, especially where piles are driven at relatively close spacing. Tests of a group of any kind of piles sometimes disclose that the safe load sustained by a group is not as high as, or the equivalent of, the results which might be anticipated by testing one pile, and then multiplying its value by the number of piles in the group.

The specification for the proposed building code, City of New York, covering tests of bearing piles, reads as follows: "Tests shall be made with 150% of the proposed load and shall be considered unsatisfactory and the results unacceptable if after standing 24 hours without settlement, the total net settlement after deducting rebound is more than 0.01" per ton of total test load."

Piles should be allowed to stand at rest for several days after driving, before test loads are applied. The vibration set up in a pile during driving draws excess water to sides of the pile which tends to form a wet mud and lubricate the sides of the pile, thus reducing bearing capacity. After the pile has been at rest for a time, the excess water is reabsorbed by the surrounding soil which increases the coefficient of friction and the bearing capacity of the pile.

Methods of Making Pile Loading Tests:

The most convenient way of testing steel bearing piles is through the use of the hydraulic jack.

The simplest and least expensive method is to drive groups of three piles in a line. A top cross beam or yoke is attached to the two outside piles, which act as anchor piles. A hydraulic jack is placed under the cross beam so as to exert a downward pressure on the center pile, whose resistance to penetration and capacity can then be ascertained with accuracy. This method is possible only where the resistance to pulling or skin friction alone of two piles is more than equivalent to the combined skin friction and point resistance of a single pile. The anchor values of Class I piles, especially those of short length, may be inadequate for this kind of a test. In the case of Class II piles the anchor values are generally adequate and usually range from at least half up to full load capacity. Anchor piles should not be driven deeper than the loaded pile. See diagram A.

Another convenient way of using a hydraulic jack is to build a suitable platform upon a pair of transverse girders and supporting cribbing and then loading the platform with the required gross weight of heavy material to produce the necessary test load. A hydraulic jack is then placed between the loaded platform and the pile, or group of piles. See diagram B. This method is best for Class I piles and has the advantage of permitting the preparation of a stable base for the platform directly on the ground around the pile or piles tested.

The preceding method is most suitable when testing groups of 3 to 5 piles. In this case the load is centered over the pile group. A slab or grillage of steel is placed over the piles to be tested. A hydraulic jack is used over the center of moments or gravity of the pile group. If two or more jacks are coupled in tandem, their group center must coincide with that of the pile group.

A conventional method of testing is by means of a sand box built around the pile and resting on suitable brackets or shelf angles attached to the pile. As a safety measure, cribbing should be placed under the sand box, or the loading platform if one is used, the cribbing being brought up almost to the under side but not quite touching the platform. The top of the pile should be stayed with lateral bracing or guides extending out at a considerable horizontal angle so as not to produce a vertical component. See diagram C.

• PERMANENCE •

The Historical Section at the beginning of this booklet gives striking examples of the long life of steel bearing pile structures. In the State of Nebraska, examination of hundreds of bridges resting on 5-inch and 8-inch I-Beams and 8-inch H sections which have been in service 25 to 35 years, showed little, if any, deterioration at 18 inches below stream bed or ground water line. At points 12 inches above normal water line, the loss of metal averaged only 1% in 20 years, or 1/20th of 1% per year. The same condition was found in a group of similar bridges around Chatham, Ontario. Steel sheet piling, withdrawn when rebuilding a bridge pier in the Monongahela River at Pittsburgh, showed practically no loss of metal below the water line after 19 years' service. Sewer liner plates, uncovered after 18 years' exposure to soil at Newark, N. J., showed loss of metal too slight to

SUMMARY OF DATA ON CORROSION RESISTANCE

FRESH WATER

Corrosion Report No.	Kind of Section	Location	Length of Exposure	Total Loss of Section
1	Jackson Steel Sheet Piling	Randolph St. Bridge, Chicago, Illinois.	30 years below water do do above water	Condition—Excellent Condition—Poor
2	U. S. Steel, Friestedt and Jackson Piling	Chicago & Western Indiana Bridge, Hegewisch, Illinois.	20 years	Condition—Excellent
3	Carnegie Friestedt Piling	Remains of Temporary Coffer-dam, Loomis St. Bridge, Chicago, Ill.	28 years in sheltered location exposed one side, loose debris on other	Condition—Very good
4	Friestedt Steel Piling	Calumet River, West Side, Columbia Ave., Hammond, Indiana.	20 years	Condition—Excellent
5	Carnegie Symmetrical Interlock Piling	Wharf, Michigan Limestone Company, Calcite, Michigan.	19 years in submerged mud do in water do in atmosphere	None—Thickness still above theoretical rolled thickness of .400 in. 0.004 in. at one point in cross section only. None—Thickness still above theoretical rolled thickness of .400 in.
6	Lackawanna Steel Piling	Calumet River, West Side, Columbia Ave., Hammond, Ind.	20 years	Condition—Excellent
7	U. S. Steel Sheet Piling M101	Calumet River, East Side, Columbia Ave., Hammond, Ind.	20 years	Condition—Excellent
8	U. S. Steel Sheet Piling M101	Tenth St. Bridge Pier, Pittsburgh, Pa. Piling 24 ft. long.	19 years 1½ ft. above average water level 6½ ft. in water 7½ ft. in soft mud 10 ft. in hard mud & gravel	14.9% 0.0% 0.4%
9	5 in. and 8 in. I-Beams 8 in. H Sections	Hundreds of Bridges State of Nebraska.	25 to 35 years	1% in 20 years
10	do	Several Bridges State of Nebraska.	do	2 to 2½% in 20 years
11	8 in. I- Beam 17.3 lb.	St. Francis River Bridge, Lake City, Arkansas.	21 years alternate wet and dry above ground level in stream bed.	4% at ground level
12	10 in. Girder Beam 41.5 lb.	Platte River Bridge, Meridan Highway South of Columbus, Nebraska.	22 years alternate wet and dry above ground level in stream bed.	Reduction in thickness between pits on opposite surfaces not greater than $\frac{1}{16}$ in. or $\frac{1}{32}$ in. from one surface.

ıeasure. Blue black mill scale was still on the plates. Bearing piles removed after 21 years of service at ,ake St. Francis, Arkansas, show that they would ave had a useful life of from 50 to 100 years.

Steel tubular piles uncovered after more than 25 ears of service in a New York City foundation, were arefully cleaned and calipered and showed in no case loss of metal of more than 1/64-inch.

Inspection of eight steel sheet piling structures in service from 17 to 31 years in salt water along the Atlantic Seaboard, all but one in the tropics, showed practically no loss of metal below the water line. Similar conditions were observed in the examination of twelve similar structures in fresh water after 19 to 30 years' service.

Following are tabulations showing the actual condition of the structures referred to in the preceding paragraph.

ıF STEEL SECTIONS IN SOIL AND WATER

:XPOSURE

Yearly Loss of Section	Analysis of Steel	General Remarks
	Standard Piling	This is the first known permanent installation of steel sheet piling in this country. Piling examined near sewer outlet, so water although fresh, undoubtedly had high free acid content. Bolt heads still show square at water line in photograph taken in 1930. Piling driven in 1901.
	Standard Piling	
	Standard Piling	
	Standard Piling	River has high acid content. Piling driven 1910. Mill brand marks visible in photograph taken in 1930.
None	Standard Piling	This piling was in practically new condition when pulled in 1931. It was redriven in another location.
Practically nothing		
None		
	Standard Piling	River has high acid content. Piling driven 1910. Paint marks placed at rolling mill still visible in photographs taken in 1930.
	Standard Piling	River has high acid content. Piling driven 1910. Paint marks placed at rolling mill still visible in photographs taken in 1930.
0.78% at water line. 0.0% at middle of pile 0.021% at bottom of pile.	Carbon 0.22 per cent. Manganese 0.44 per cent. Phosphorus 0.011 per cent. Sulphur 0.035 per cent. Silicon 0.032 per cent. Copper 0.01 per cent.	With exception of 3½ feet at top of pile, 1½ ft. above water line, and 2 ft. below the water, very little rusting or pitting was noticeable. During the major part of the year, the Monongahela River contains free sulphuric acid. Data from report "Condition of Steel Sheet Piling," by Dr. J. S. Unger, Research Engineer for Carnegie Steel Company.
0.05% Fresh water 12 in. above water line. At 18 in. below stream bed or ground water, little, if any, deterioration.	Structural Grade	Data from paper "Steel-Pile Foundations in Nebraska," from "Civil Engineering," September, 1932, by J. G. Mason and A. L. Ogle.
0.12% Salt Creek Valley. 12 in. above normal water line.	Structural Grade	
0.19% at ground level.	Carbon 0.29 per cent. Manganese 0.49 per cent. Phosphorus 0.016 per cent. Sulphur 0.034 per cent. Silicon 0.019 per cent. Copper 0.010 per cent.	Top portion of pile was free from pitting, while the bottom portion, or that at the ground level, had a few shallow pits but not of sufficient volume to make any perceptible difference in the weights of the respective specimens. From report by Dr. J. S. Unger, Research Engineer for Carnegie Steel Company.
		Upper 8 feet of pile which was in air, but slightly pitted. These piles were pulled on account of abandonment of bridges due to obsolescence. These piles are to be used by the county for other bridge work. They will be turned end for end so that the slightly damaged end will be driven far below flow line. Data submitted by J. G. Mason, Bridge Engineer, State of Nebraska.

SUMMARY OF DATA ON CORROSION RESISTANCE

SALT WATER

Corrosion Report No.	Kind of Section	Location	Length of Exposure	Total Loss of Section
1	6 in. diameter solid steel	U. S. Navy Department Piers, Dry Tortugas Islands in Gulf of Mexico, 75 miles NW of Key West, Fla.	31 years	.25″ corrosion penetration 3″ from top .22″ do do 12″ do .06″ do do 24″ do .06″ do do 36″ do * .03″ do do 51″ do *Approx. Mean Low Water Level.
2	Steel Sheet Piling	Municipal Wharves, Jacksonville, Fla.	22 yrs. about 10 ft. above water line, protected by fill on one side. do just above water line.	Condition—Excellent Condition—Fair
3	Carnegie Steel Co. Friestedt Piling	Ferry Slip, Florida East Coast R. R., Key West, Florida.	19 yrs. below low water mark. do between high and low water mark with earth on one side. do at top exposed both sides to salt spray and wave action.	Condition—Practically good as new Condition—Excellent Condition—Poor
4	U. S. Steel Sheet Piling	Piers and Abutment, Florida East Coast Railway, West Drawbridge, Key West, Fla.	20 yrs. below low salt water mark. do above low water protected by earth on one side. do in atmosphere open both sides subject to salt spray and erosion from sand laden waves.	Condition—No noticeable decrease in original thickness of metal Condition—Still serviceable Condition—Webs entirely corroded
5	U. S. Steel Sheet Piling M-104	Sea Wall, Fort St. Phillip, Louisiana.	23 yrs. to atmospheric corrosion. do on salt water side just below surface of ground. do in well for gate valves. do on fresh water side just below surface of ground.	Condition—Good at bottom of manhole Condition—Very good Condition—Fair Condition—Excellent
6	U. S. Steel Sheet Piling M-104	Brooks-Scanlon Corp. Pier, Eastport, Fla.	17 years	Condition—Excellent
7	⅜ in. thick Sheet Piling	Glenwood Landing, Long Island, N. Y.	21 years	.09 in. or 24%
8	do	do	11 years	.045 in. or 12%

SOIL

Corrosion Report No.	Kind of Section	Location	Length of Exposure	Total Loss of Section
9	⅜ in. thick, actual .409 in., Carnegie M-104 Sheet Piling	Lafayette & Flatbush Aves., Brooklyn, N. Y., Old Subway Tunnel.	26 years	Average .072 in. or 18% Max. .108 in. or 26%
10	⅛ in. thick Sewer Liners	12 in. Concrete Lined Sewer, Newark, N. J.	18 years. Outside to soil. Inside concrete lined.	Too slight to measure

OF STEEL SECTIONS IN SOIL AND WATER

EXPOSURE

Yearly Loss of Section	Analysis of Steel	General Remarks
1/124″ Depth of Corrosion 1/142″ do 1/496″ do 1/496″ do 1/992″ do		Pile encrusted with layer of scale 1″ thick. do .44″ do do .31″ do do .34″ do do .22″ do No protection except original coat of paint. Rise and fall of tide about 1½ feet. Subject to abrasion from sand laden storm waves and alternate wetting and drying. Data from "Steel in Sea Water Examined After 31 Years Exposure," by J. S. Unger, Engineering News-Record, November 16, 1933.
	Standard Piling	Horizontal channel steel wales about 5 ft. above water line practically corroded away, due to their retaining sea water and collecting salt in channel. Sheet piling, however, still vertical and shows no outward bulge, indicating retention of nearly full strength at water line.
	Standard Piling	Installation in tropical sea water, alternately wet and dry. Piling purchased 1907. Driven and redriven 12 times in temporary work. Installed permanently 1912.
	Standard Piling	Piling purchased 1906-1907. Driven and redriven 12 times in temporary work. Installed permanently 1910.
	Standard Piling	Piling given one coating of asphaltum pitch before driving. This coating protected steel only in isolated areas, as in all probability the asphaltum was abraded off during driving.
	Standard Piling	
1.14% Salt water and acid industrial waste 12 in. below high water.	Standard Piling	Unprotected Sheet Piling. From typical samples removed and in office of Recorder, Beach Erosion Board, Washington, D. C.
1.14% do		

EXPOSURE

0.7% 1% Ground saturated first 6 years and water drained from around excavation last 20 years. Also alternate wetting and drying. Blue black mill scale still on plates.	Standard Piling	The timbering left in place, except that embedded in concrete, had rotted or disappeared. While conditions were not as favorable for preservation of steel, as if entirely submerged, the only deterioration was the rusting noted. Data from report by J. C. Meem, Consulting Engr., 149 Ramsen St., Brooklyn, N. Y. From report "Liner Plates 18 Years Old Show Little Corrosion," by J. S. Unger, Research Engineer, "Engineering News-Record," March 16, 1933.

Item	Plate A	Plate B
Carbon	0.13	0.11
Manganese	0.38	0.35
Phosphorus	0.013	0.019
Sulphur	0.056	0.041
Silicon	0.008	0.008
Copper	0.04	0.05

CORROSION RESISTANCE AND PROTECTION AGAINST CORROSION

The low, unit working stresses found in steel bearing pile designs provide ample safeguards against high stresses in the piles in the event that through some unusual circumstances the loss of metal should be appreciably greater than that which many years' experience over a wide range of conditions has indicated.

A variety of protective encasements for steel bearing piles, where they extend above the low water line, are shown in this booklet.

In their vertical position steel bearing piles do not offer convenient paths for the conduction of stray electric surface currents, so there is little likelihood of their being damaged by electrolysis due to such currents.

Basically, the surface corrosion of steel is proportionate to the amount of moist atmosphere and dissolved or free oxygen coming in contact with it. It is also well known that the rate of corrosion slows up materially as soon as the steel takes on a film of products of corrosion, which in themselves act as a protection for the metal underneath. These products of corrosion also permeate the ground, under certain conditions of earth and moisture for several inches, forming a dense non-porous and impervious encasement around the steel.

Where steel piles are driven in sand, conditions are particularly favorable to the formation of an impervious, insoluble coating of ferro-silicate as soon as the steel corrodes slightly, thus forming an encasement which is effective in preventing further corrosion.

In subgrade structures such as foundations, it is apparent that fresh oxygen cannot be brought to the steel either by penetration of air or by sub-surface water currents, so no special protection for the steel is required.

In structures such as pile bents, which extend continuously from below a stream bed up to points considerably above high water, some form of protective encasement is desirable in the zone of maximum corrosion, which is usually between the low and high water marks. The encasement should begin at a point about a foot or more below low water and extend up to a point above high water, where maintenance such as painting as applied to the balance of the structure is practicable. Wide flange CB section steel bearing piles, protected as just stated, will certainly have a useful life at least equal to other types of supports which have been generally used heretofore.

As previously stated, steel bearing piles are, of course, immune from attack and destruction by various types of borers, such as teredos, bankia, martesia, limnoria, sphaeroma or other marine organisms, as well as any kind of insects such as ants or termites.

On this subject Mr. J. G. Mason, Bridge Engineer of the State of Nebraska, writes as follows:

"Now with regard to corrosion factors:

"It has been our experience and is borne out by your compilation that the only weak place in a steel pile as far as corrosion is concerned is in the region of the water line, ground line or air line. Generally, this dangerous region is within a pretty well defined range 3 feet in extent. In Nebraska we are now quite content to encase the pile in concrete for a distance of one foot above and three feet below that plane. In addition we call for three good coats of red lead paint from the top of the pile to a distance of 10 feet below ground line.

"We have visible instances where scores of steel piles without a vestage of encasement other than paint have functioned for 20 odd years without appreciable deterioration.

"We believe that with our present treatment as described above our piles will remain in a good condition for at least 50 to 80 years. Furthermore, we feel assured that it would not be difficult to renew the protection whenever they do show signs of corrosion.

"Even without protection it would not be so difficult or expensive to cut out bad sections at the ground line and to insert and weld in new sections. This operation could be done one pile at a time without disturbing traffic."

The many examples of the use of steel bearing piles as shown herein offer convincing proof of the widespread acceptance of rolled steel bearing pile sections.

RECOMMENDED FORMS OF PROTECTION AGAINST BOTH ABRASION AND CORROSION

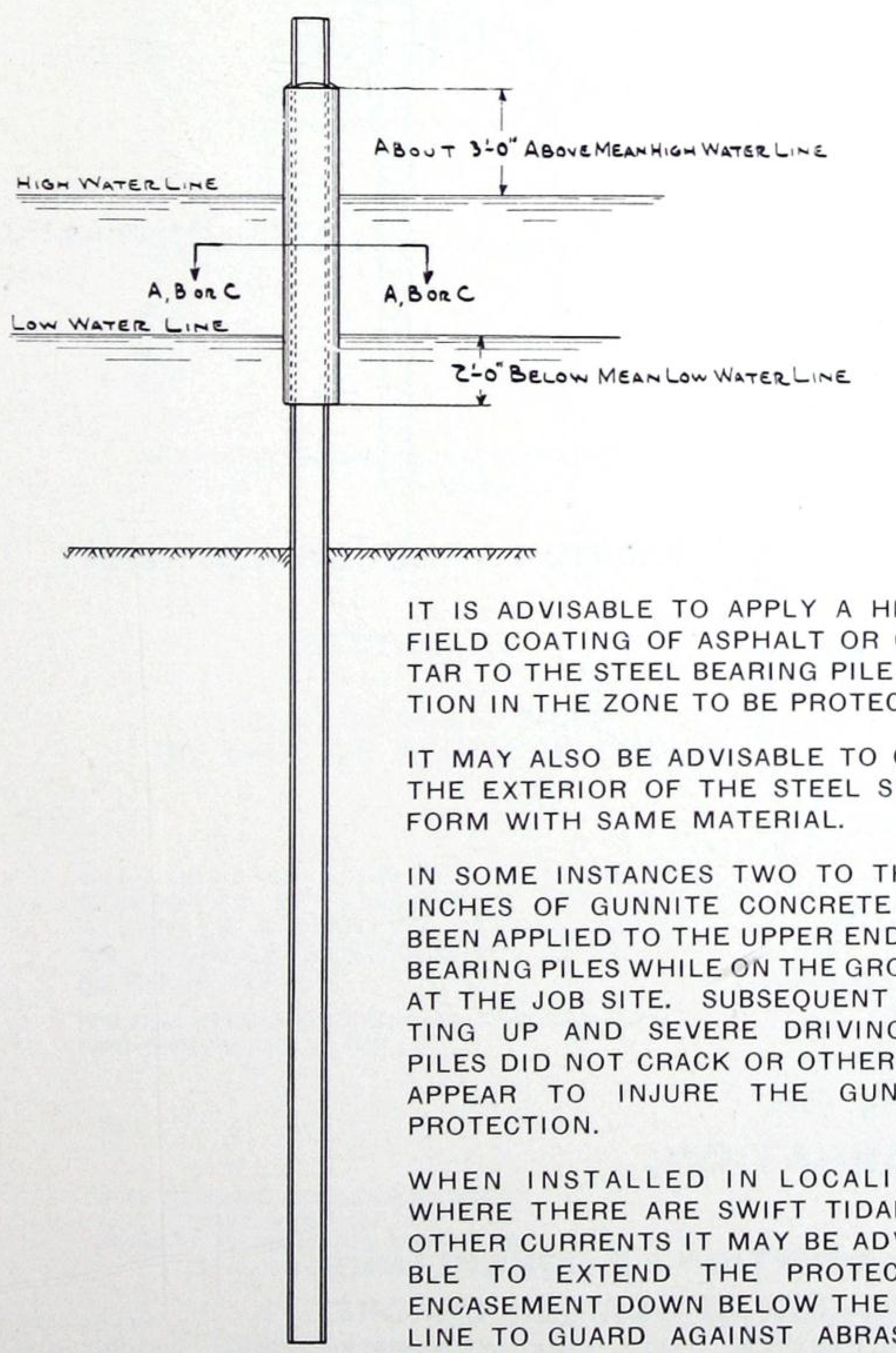
Experience indicates the desirability of protecting steel bearing piles from a point below low water up to some distance above high water. The distance the protection extends above high water is dependent on the degree of exposure of the structure which governs the height and character of wave action. Along rivers and protected sites 2 to 3 feet above high water line is sufficient. Along exposed beaches or on the shores of any large bodies of water the protection may have to be carried up to considerable height in order to get above prevalent height of waves during rough weather.

It is recommended that the bearing piles themselves be swabbed with a heavy coating of tar or asphalt applied hot before they are driven. After piles are driven, steel cylinders with their inside surfaces heavily coated should be placed around the piles and the space about the pile filled with concrete. It is also highly desirable that the exterior surfaces of the steel shells be coated with tar or asphalt.

A tar or asphalt coating is particularly efficacious in protection against abrasion. It appears that particles of sand and gravel carried by the waves embed themselves on the asphalt or tar surfaces so that succeeding particles of sand and gravel are impinged on an abrasion resisting sanded surface formed at the face of the tar or asphalt. The thick coating, therefore, picks up and supplies its own wearing surface.

These coatings can be renewed from time to time as required at very little expense.

Illustrations below show various forms of steel shells. As indicated, their thickness may vary from the lightest sheet metal up to steel sections of substantial thickness.

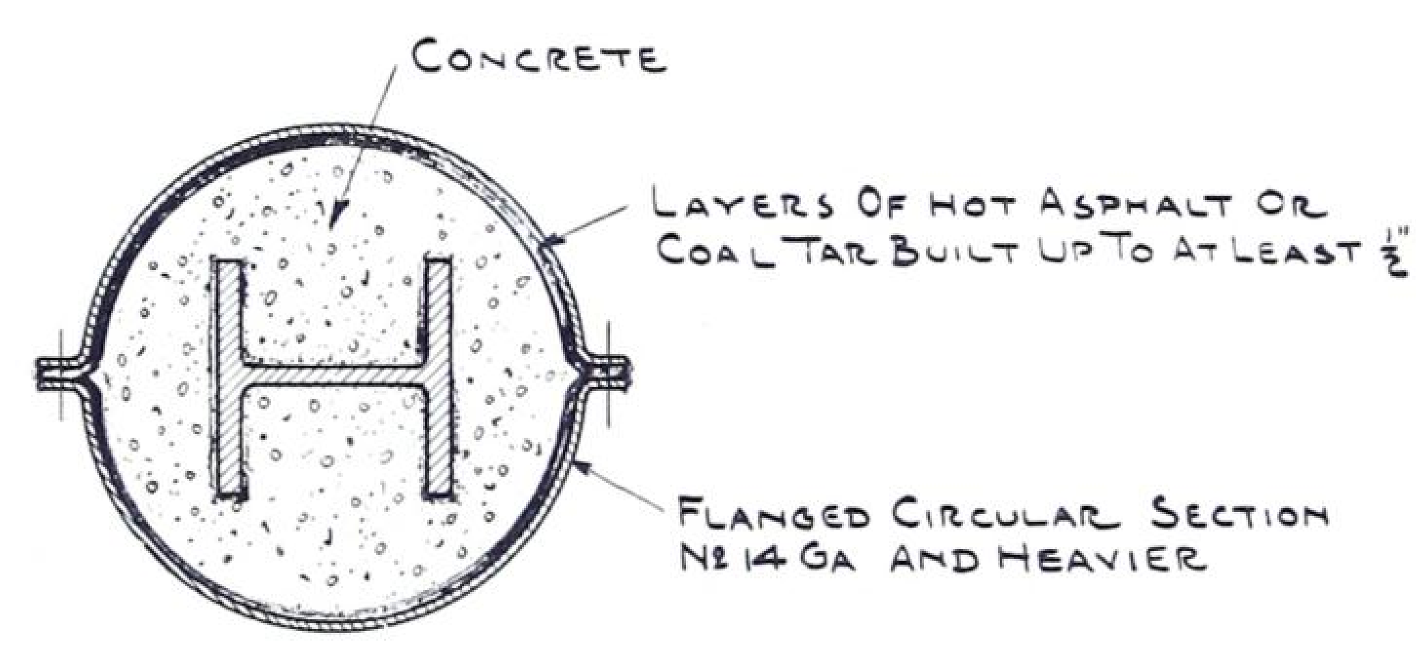


IT IS ADVISABLE TO APPLY A HEAVY FIELD COATING OF ASPHALT OR COAL TAR TO THE STEEL BEARING PILE SECTION IN THE ZONE TO BE PROTECTED.

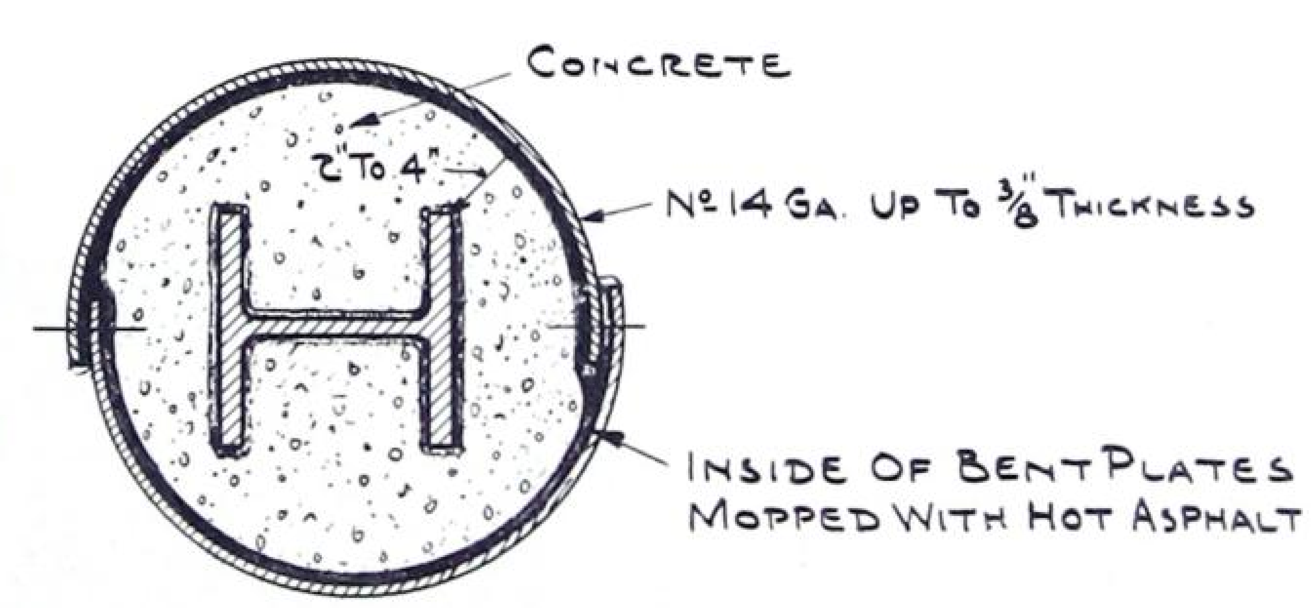
IT MAY ALSO BE ADVISABLE TO COAT THE EXTERIOR OF THE STEEL SHELL FORM WITH SAME MATERIAL.

IN SOME INSTANCES TWO TO THREE INCHES OF GUNNITE CONCRETE HAS BEEN APPLIED TO THE UPPER ENDS OF BEARING PILES WHILE ON THE GROUND AT THE JOB SITE. SUBSEQUENT SETTING UP AND SEVERE DRIVING OF PILES DID NOT CRACK OR OTHERWISE APPEAR TO INJURE THE GUNNITE PROTECTION.

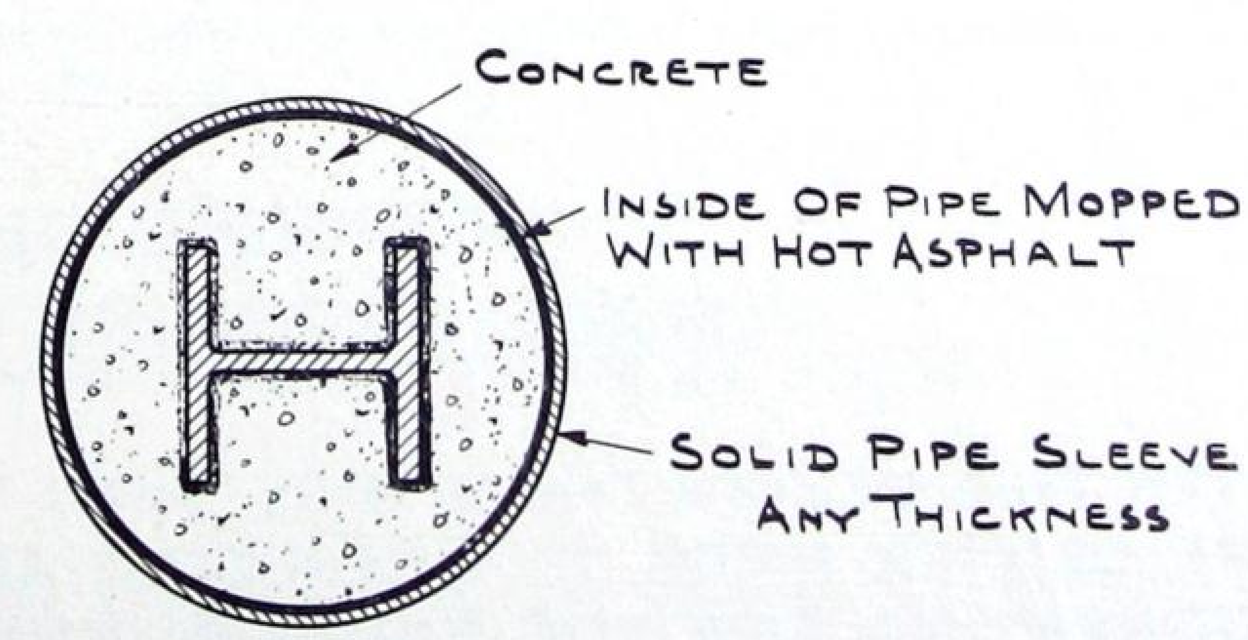
WHEN INSTALLED IN LOCALITIES WHERE THERE ARE SWIFT TIDAL OR OTHER CURRENTS IT MAY BE ADVISABLE TO EXTEND THE PROTECTIVE ENCASEMENT DOWN BELOW THE SOIL LINE TO GUARD AGAINST ABRASION, SIMILAR TO TREATMENT OF PIER PILES SHOWN ON PAGE 57.



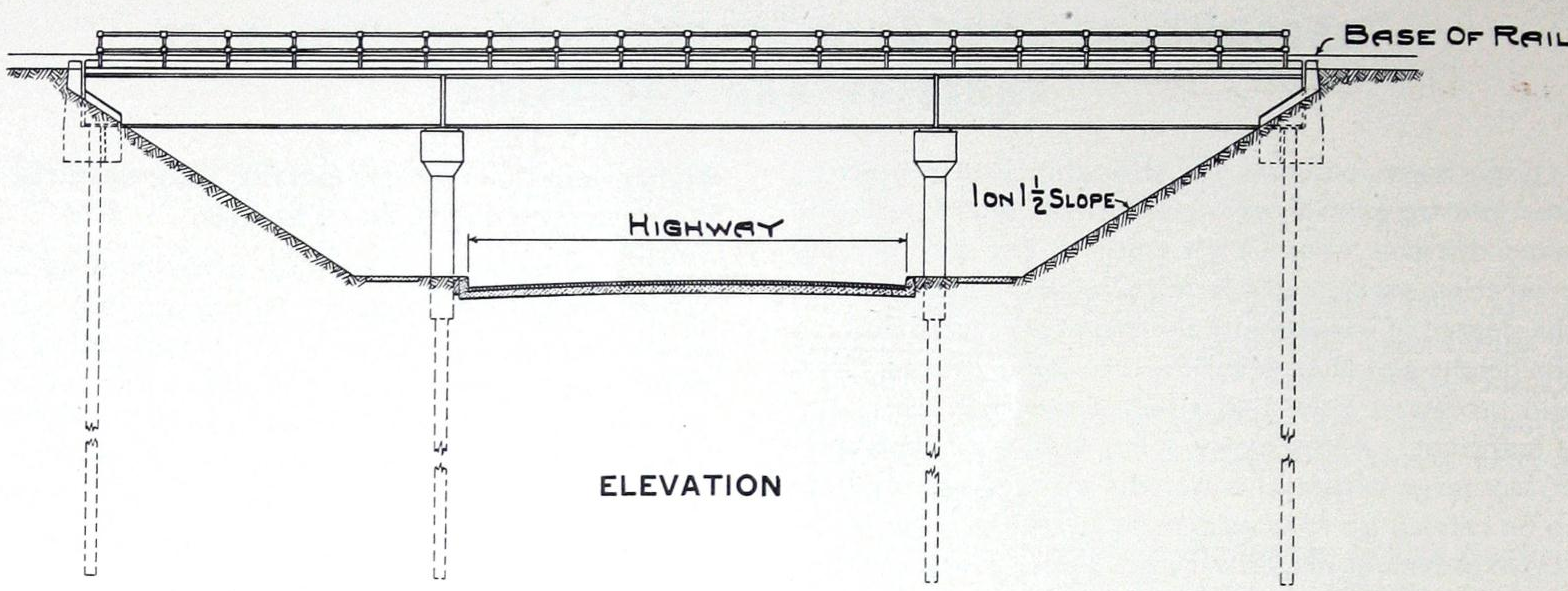
SECTION-AA.



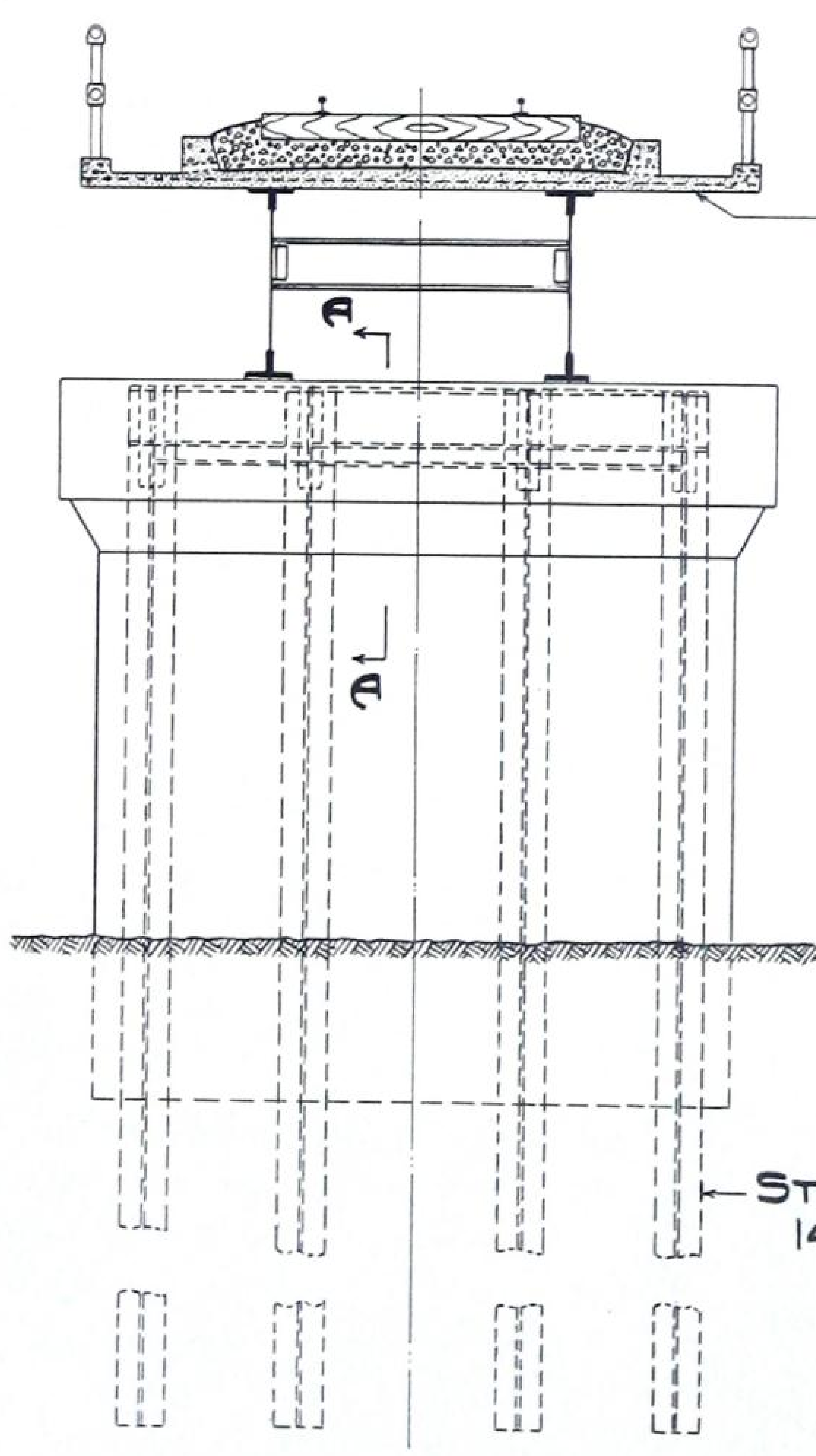
SECTION-BB.



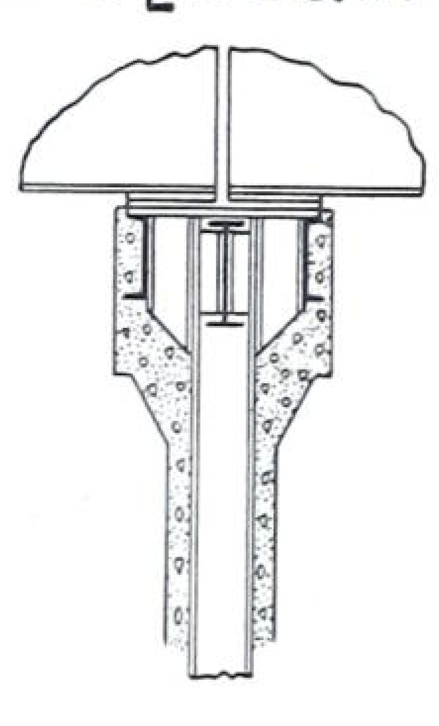
SECTION-CC.



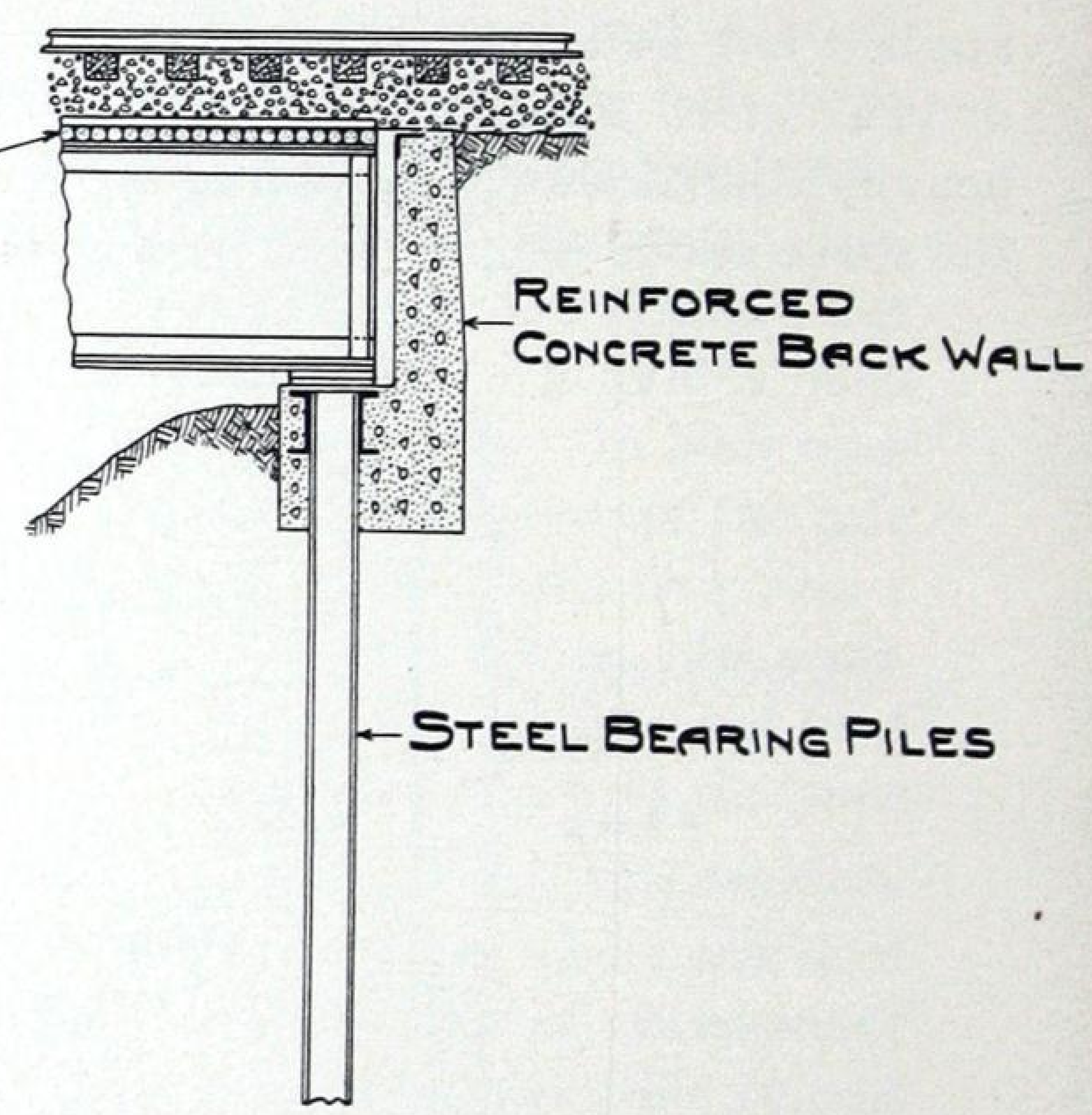
ELEVATION



DETAIL OF CENTER PIERS.



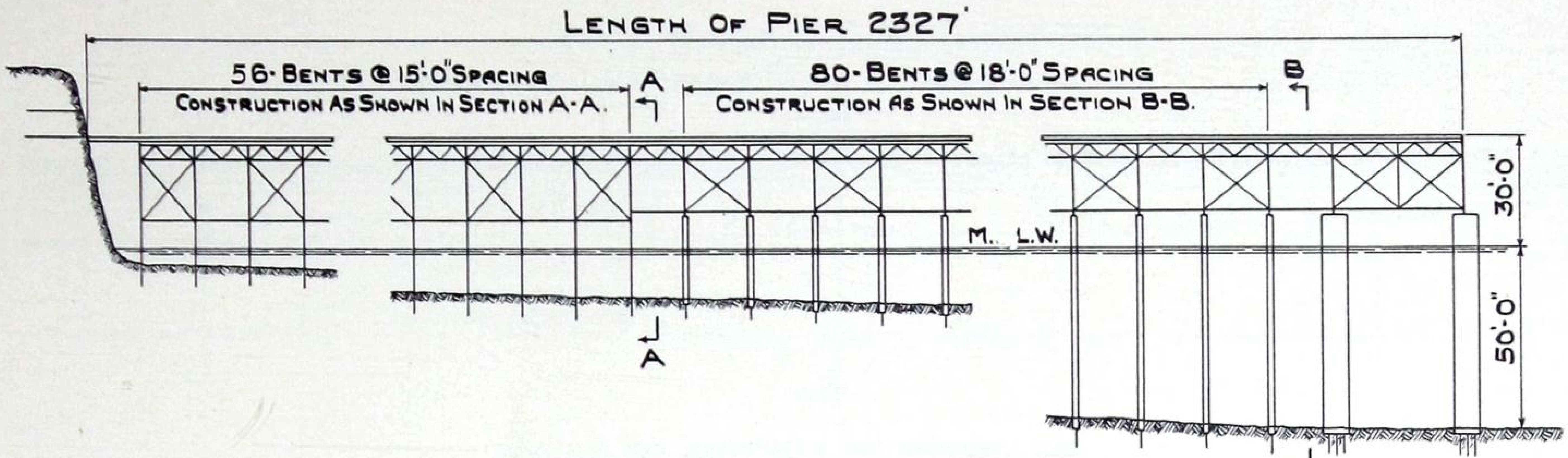
SECTION-AA.



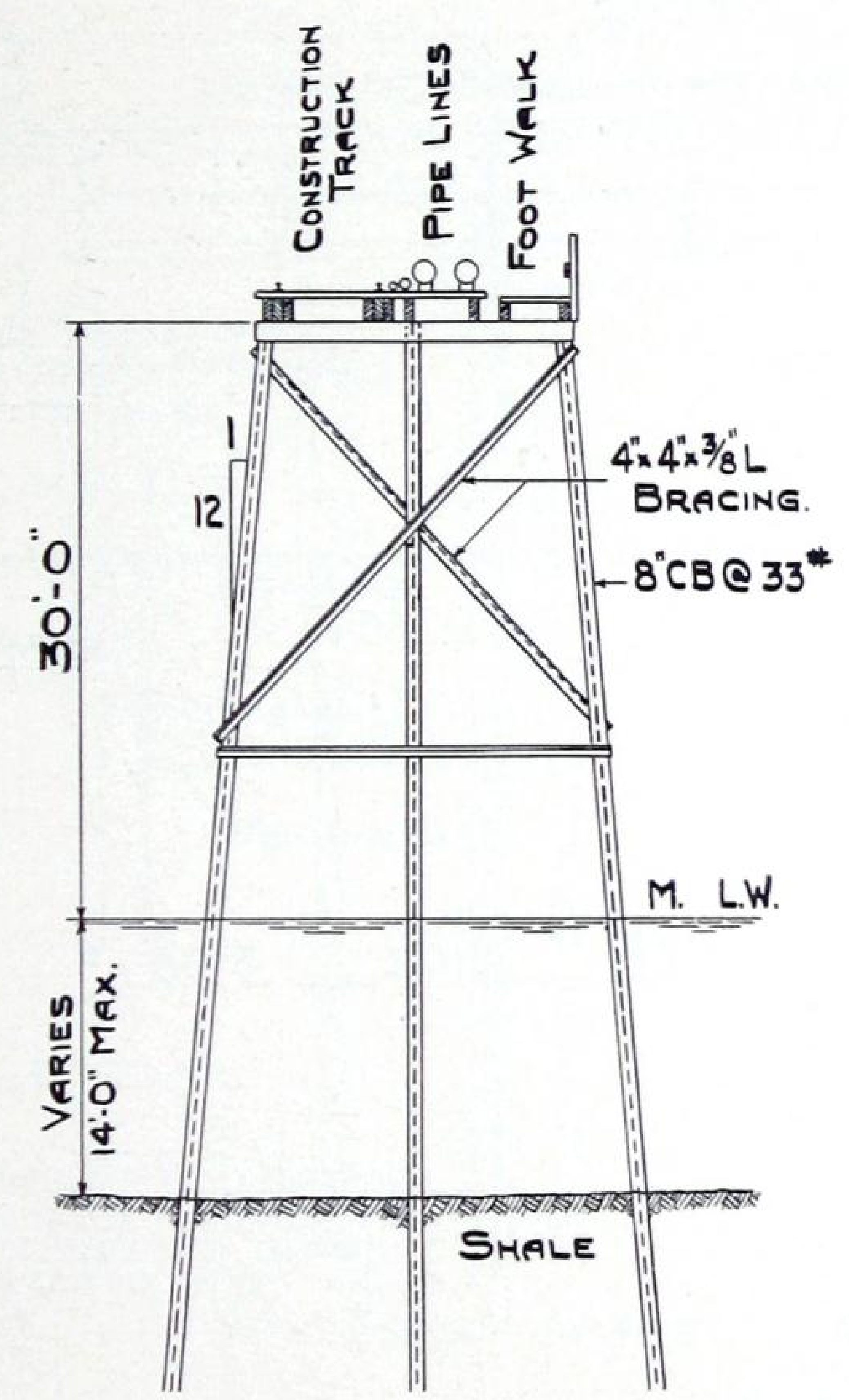
SECTION THROUGH ABUTMENT

PROPOSED DESIGN OF GRADE CROSSING ELIMINATION.

WITH THIS DESIGN THE BRIDGE, WITH THE EXCEPTION OF CONCRETING THE CENTER PIERS, IS COMPLETED AND PLACED IN SERVICE BEFORE EXCAVATING FOR THE HIGHWAY. THE CONCRETE FOR THE CENTER PIERS IS PLACED AFTER ALL EXCAVATING IS DONE FOR THE HIGHWAY.

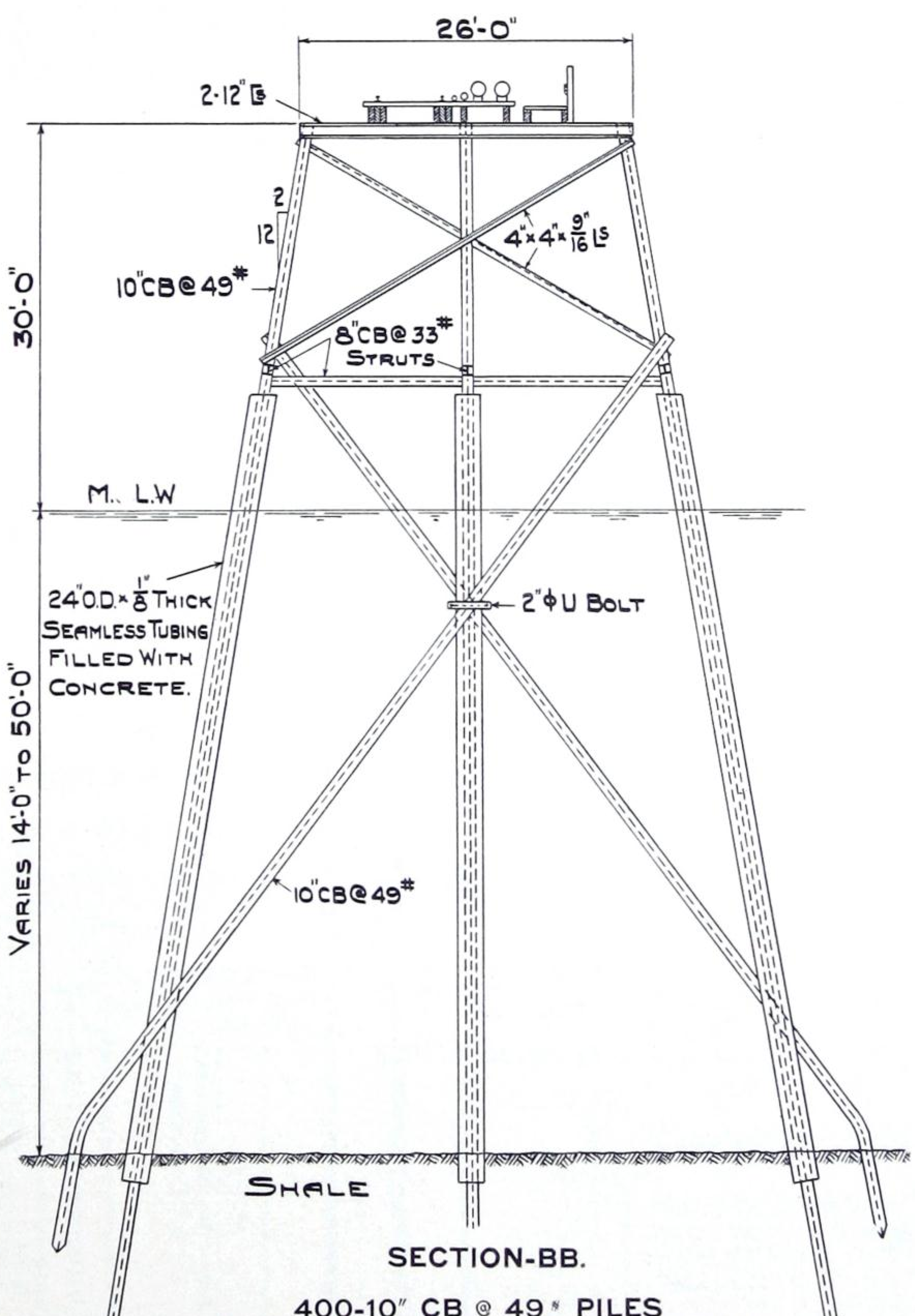


ELEVATION OF PIER



SECTION-AA.

168-8" CB @ 33# PILES
IN 56 TRESTLE BENTS AS SHOWN



SECTION-BB.

400-10" CB @ 49# PILES
IN 80 TRESTLE BENTS AS SHOWN

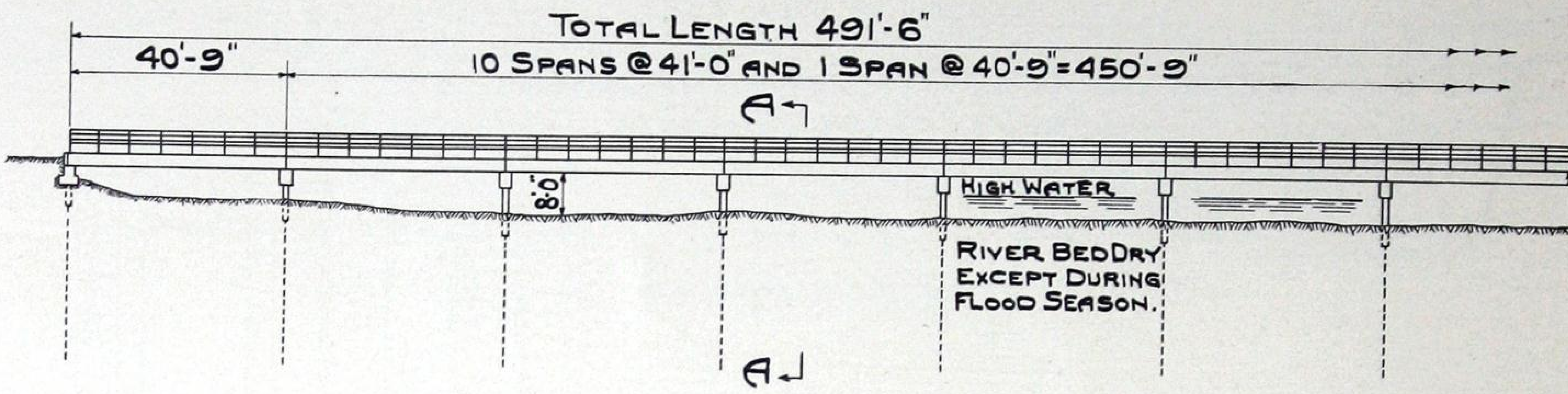
SAFE LOAD ON EACH PILE 64 TONS AS COMPUTED BY ENG.-NEWS FORMULA ALL PILES DRIVEN TO REFUSAL WITH AN AVERAGE PENETRATION OF 8 FT. IN SOLID SHALE.

FOR FULL DETAILS SEE DESCRIPTIVE ARTICLE IN ENG. NEWS-RECORD, JAN. 10, 1935.

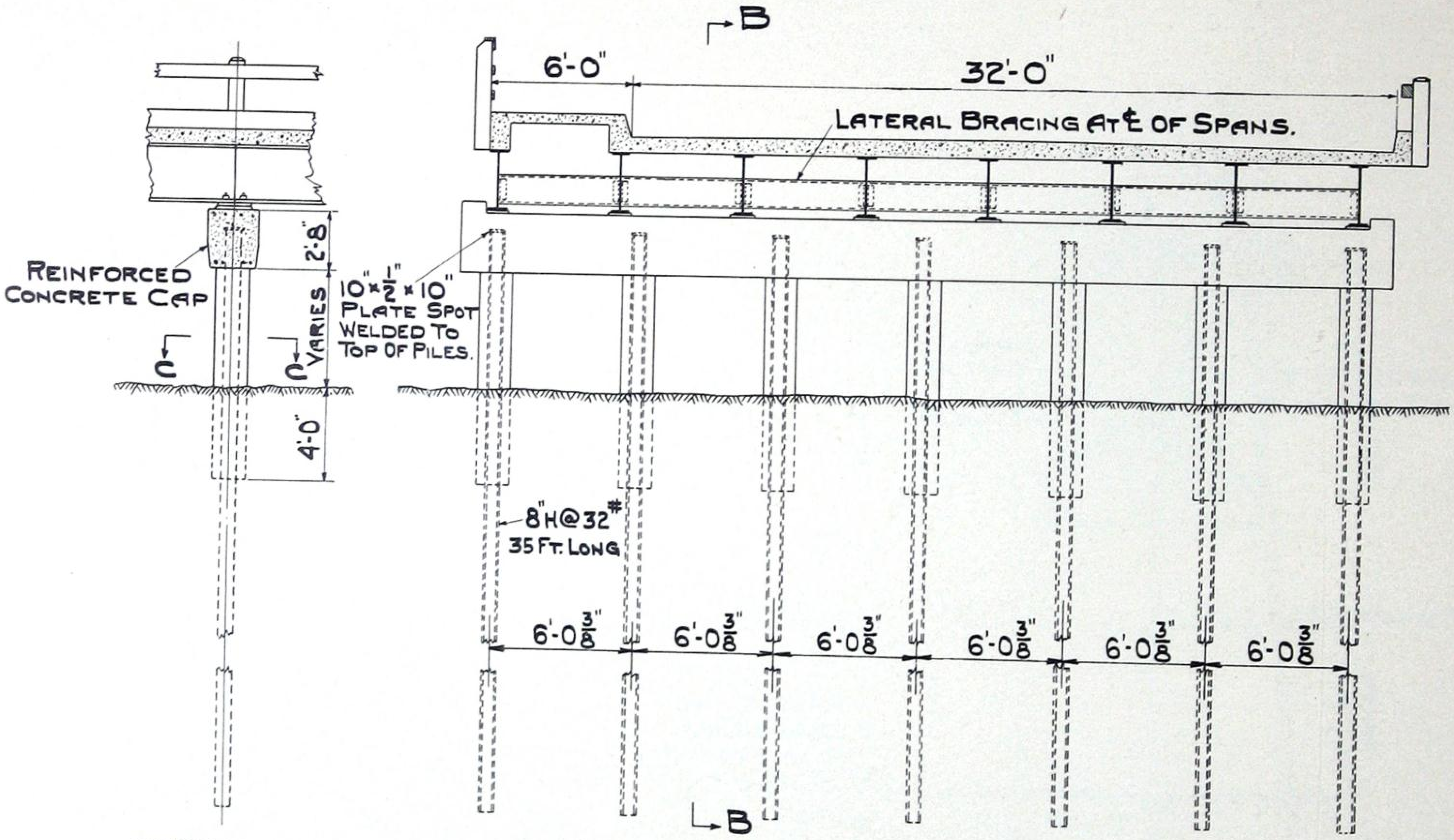
PIER DESIGNED AND CONSTRUCTED BY
WEST COAST DIVISION
MERRITT, CHAPMAN AND SCOTT CORP.
SAN FRANCISCO, CAL.

CONSULTING ENGINEERS
PARSONS, CLAPP, BRINKERHOFF & DOUGLAS
NEW YORK, N. Y.

ALL WELDED STEEL OCEAN PIER AT DAVENPORT, CAL.



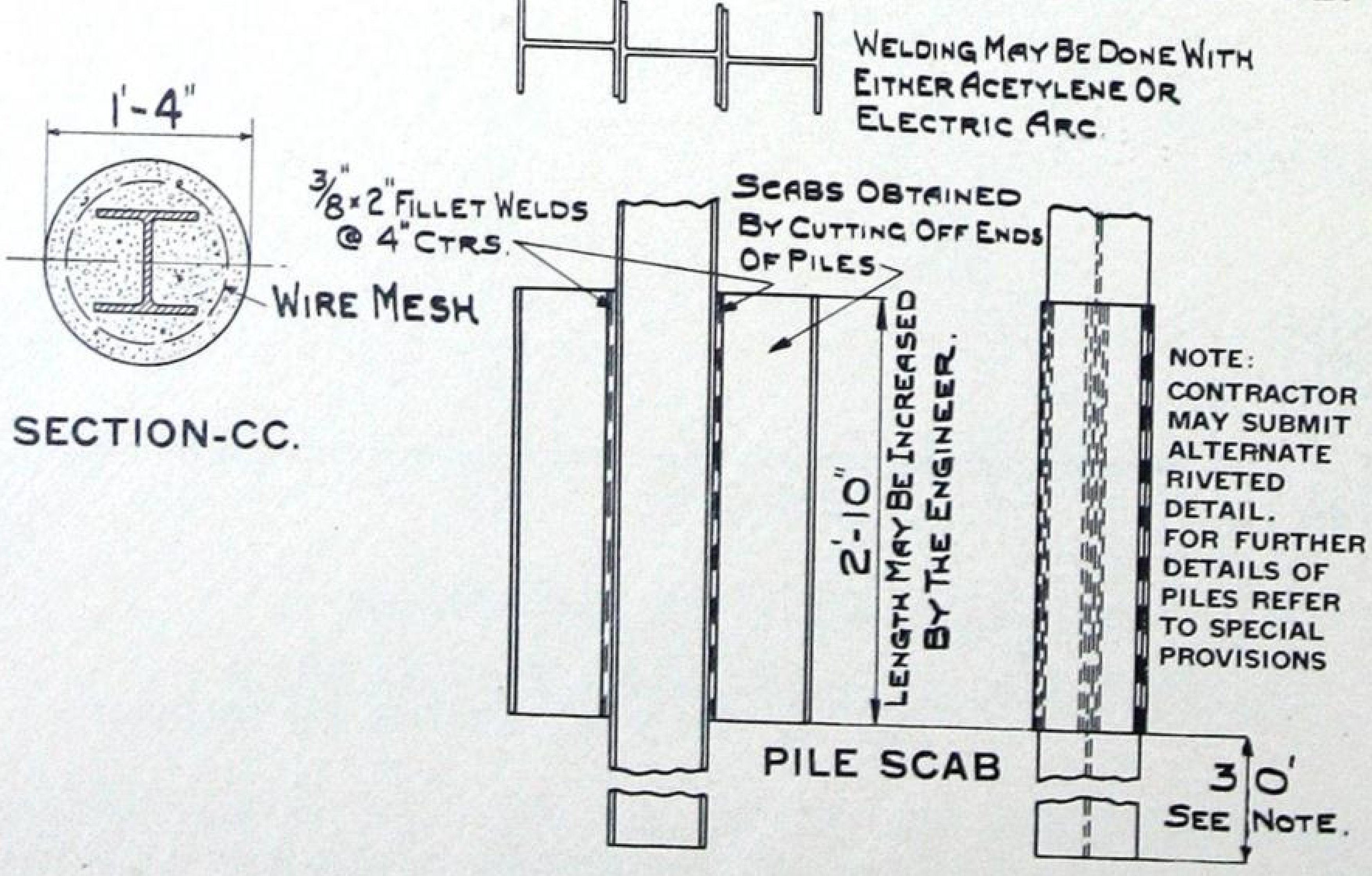
ELEVATION OF PORTION OF BRIDGE



SECTION-BB.

SECTION-AA.

91 PILES 8" H 32 LB.



SECTION-CC.

PILE SCAB

STEEL TEST PILES

EXTRACTS FROM SPECIFICATIONS

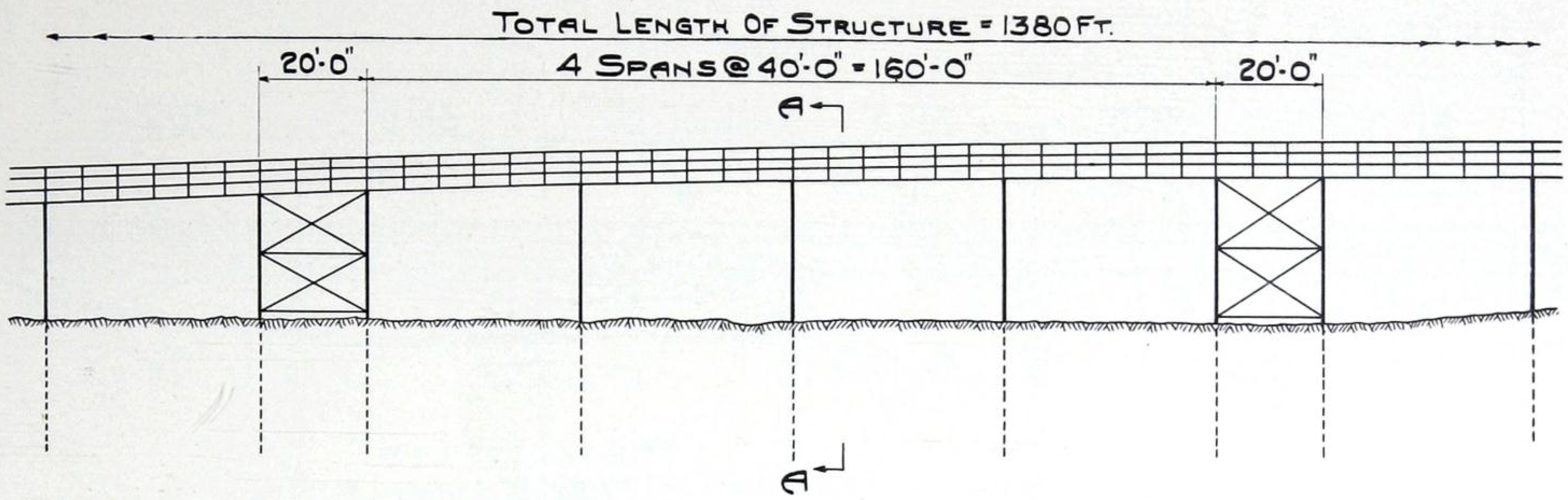
THE CONTRACTOR SHALL DRIVE THREE (3) FORTY-FIVE FOOT (45') STEEL TEST PILES AT THE LOCATIONS SHOWN ON THE PLANS OR WHERE DIRECTED BY THE ENGINEER. THEY SHALL BE OF THE SAME SECTION AS THE PILES TO BE USED IN THE BENTS AS SPECIFIED ON THE PLANS AND SHALL BE DRIVEN IN SUCH POSITION THAT THEY MAY BE CUT OFF AND BECOME A PART OF THE STRUCTURE.

IF THE REQUIRED BEARING POWER PER PILE HAS NOT BEEN OBTAINED UPON GETTING A PENETRATION OF THIRTY FEET (30') THE PILES SHALL BE SCABBED IN ACCORDANCE WITH THE DETAILS SHOWN ON THE PLANS AND DRIVEN TO OBTAIN A BEARING VALUE OF APPROXIMATELY FORTY (40) TONS.

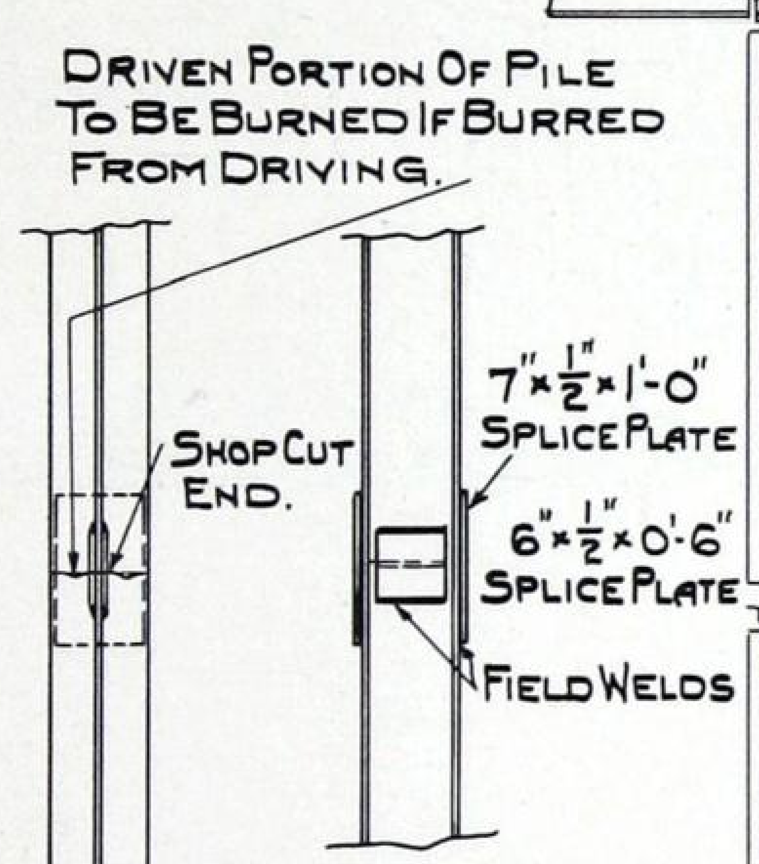
THE STATE HAS NO DEFINITE KNOWLEDGE OF THE LENGTH OF PILES REQUIRED AND FOR THAT REASON TEST PILES ARE SPECIFIED. FROM RESULTS OF THESE TESTS THE CONTRACTOR SHALL DETERMINE THE NECESSARY LENGTH OF STEEL PILES.

BRIDGE ACROSS FRESNO RIVER, MADERA, MADERA COUNTY, CALIFORNIA

DESIGNED BY
DIVISION OF HIGHWAYS
DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA.

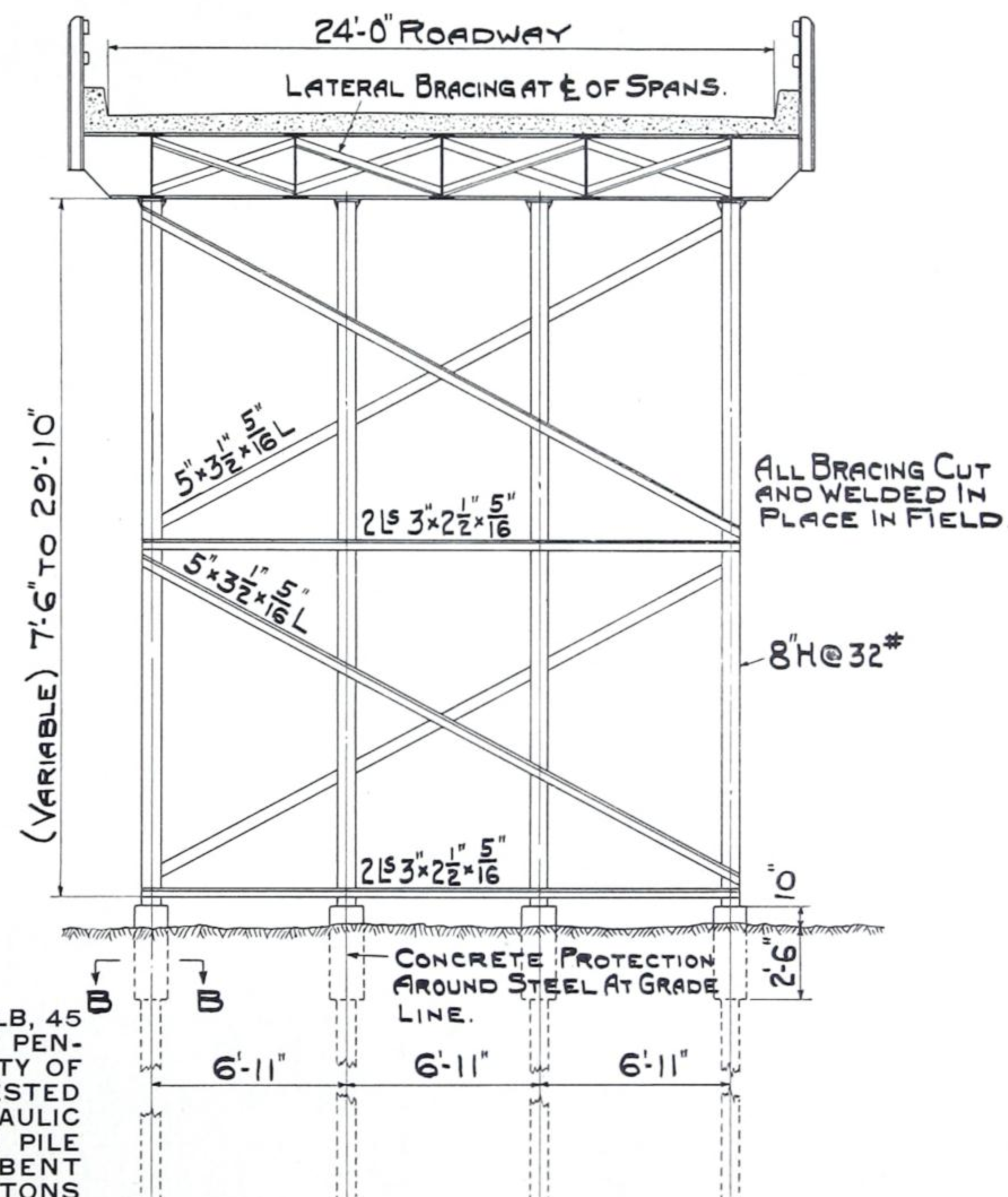


ELEVATION OF PORTION OF BRIDGE
33 COMBINATION STEEL PILE AND TRESTLE BENTS



PILE SPLICE

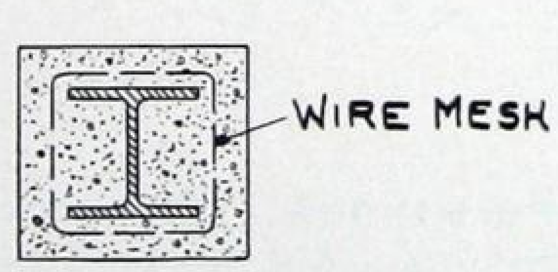
NOTE—
WELDS ABOVE JOINT TO BE MADE FIRST, THEN DROP HAMMER TWO OR THREE TIMES TO IMPROVE SPLICE CONTACTS, NEXT WELD BELOW JOINT.



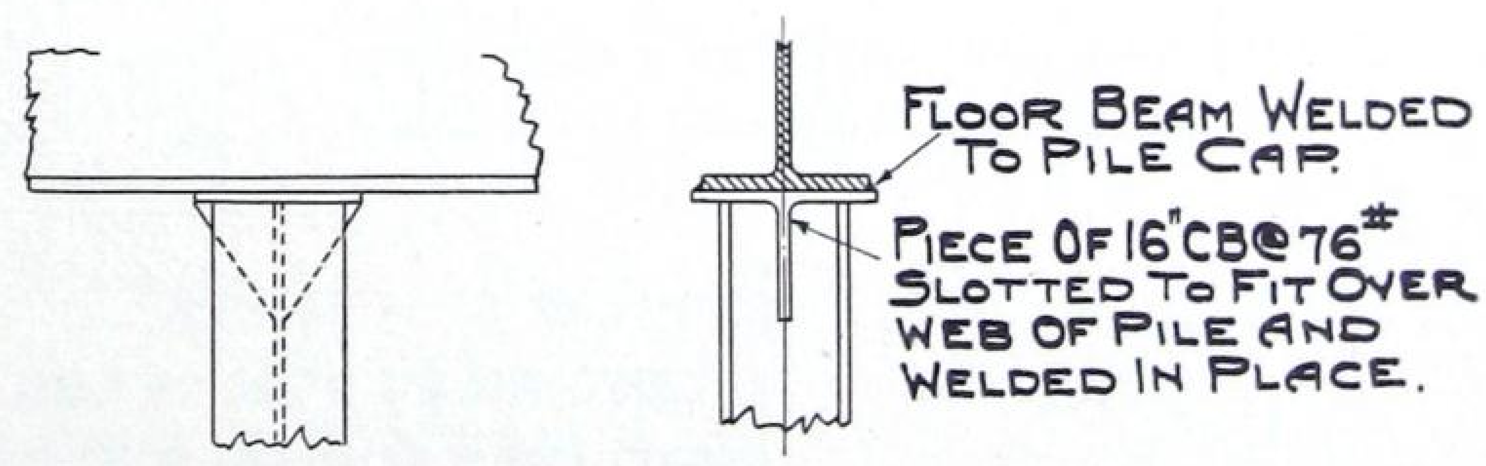
132 PILES 8" H 32 LB, 45 FT. DRIVEN TO 35' PENETRATION; CAPACITY OF SEVERAL PILES TESTED BY PLACING HYDRAULIC JACK ON CENTER PILE OF THREE PILE BENT PROVED TO BE 60 TONS AS AGAINST THE DESIGNED CAPACITY OF 30 TONS PER PILE.

SEE ENG. NEWS-RECORD OF SEPT. 10, 1931.

SECTION-AA



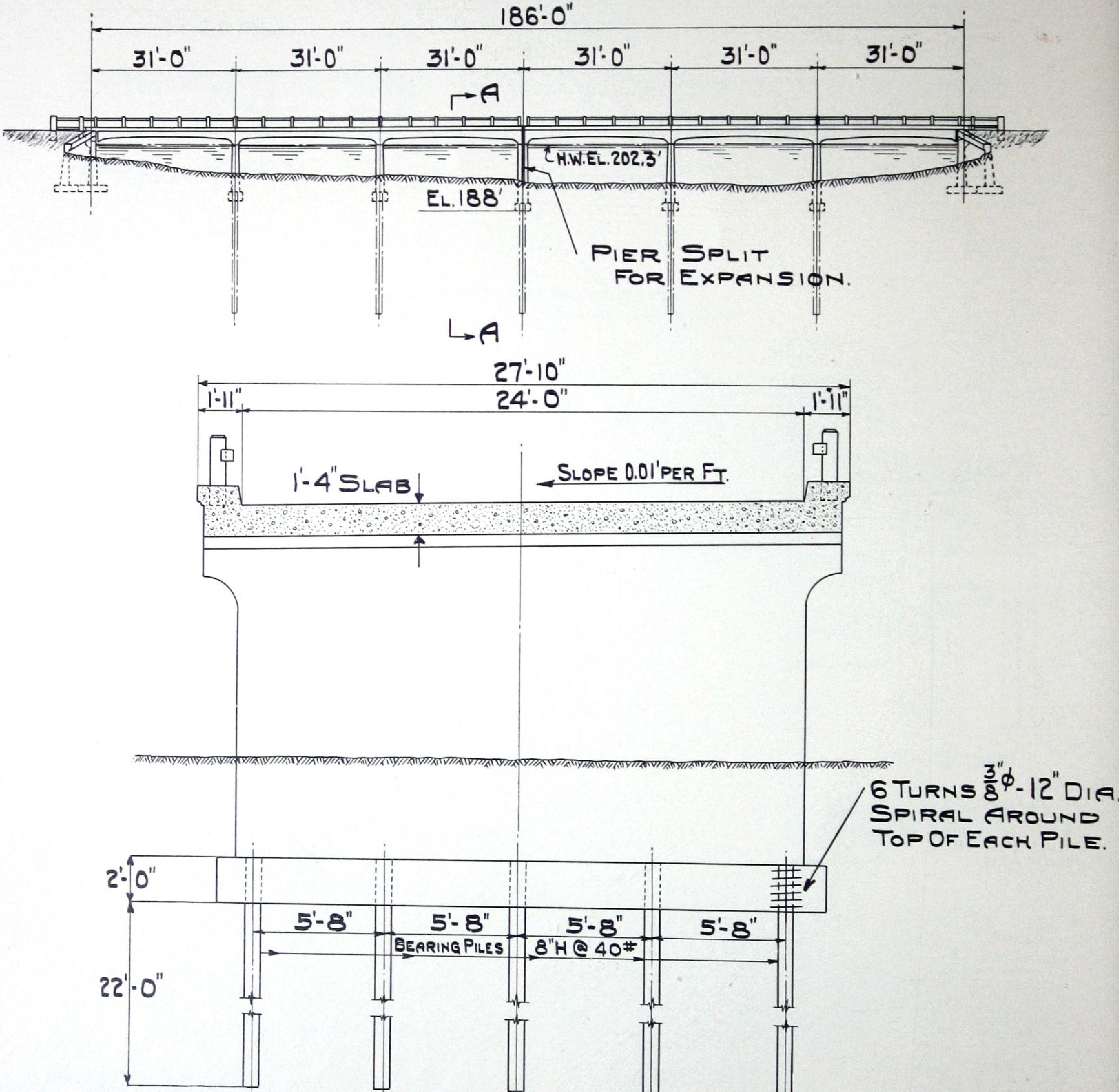
SECTION-BB.



DETAIL OF CONNECTION OF TOP OF PILE TO FLOOR BEAM

VIADUCT BRIDGE OVER THE ATCHISON, TOPEKA & SANTA FE RAILWAY MERCED COUNTY, CALIFORNIA

DESIGNED BY
DIVISION OF HIGHWAYS
DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA.



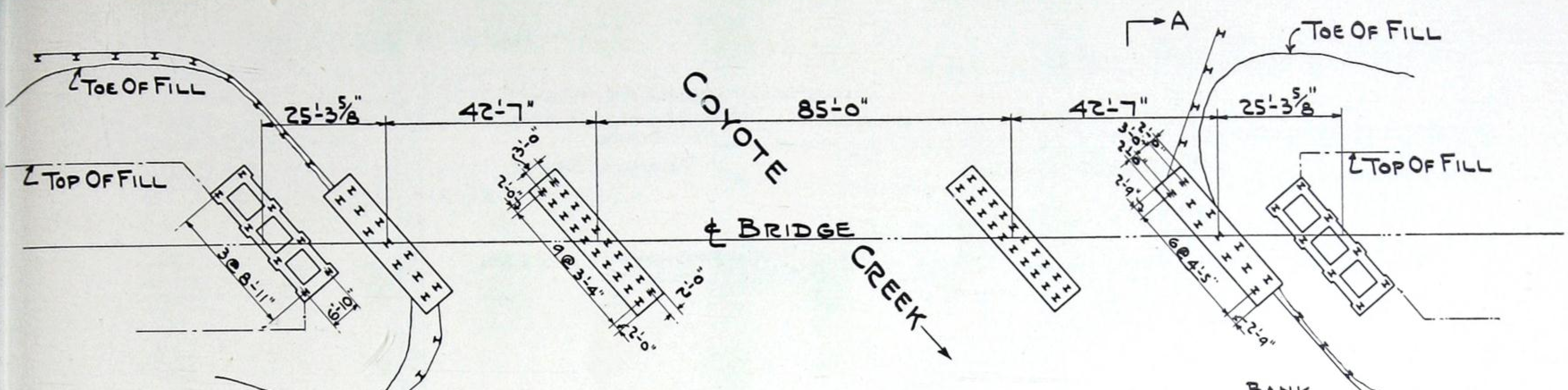
23 PILES 8″ H 40 LBS.

2 TEST PILES 8″ H 36 LBS., 24′ (Part of Permanent Construction.)

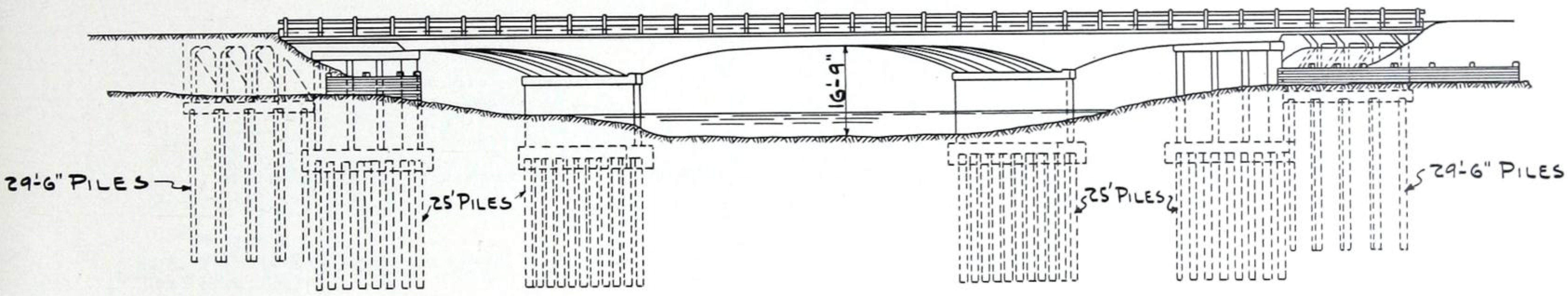
LOAD ON EACH PILE 33 TONS.

BRIDGE ACROSS PINE CREEK, BUTTE COUNTY, CALIFORNIA

DESIGNED BY
DIVISION OF HIGHWAYS
DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

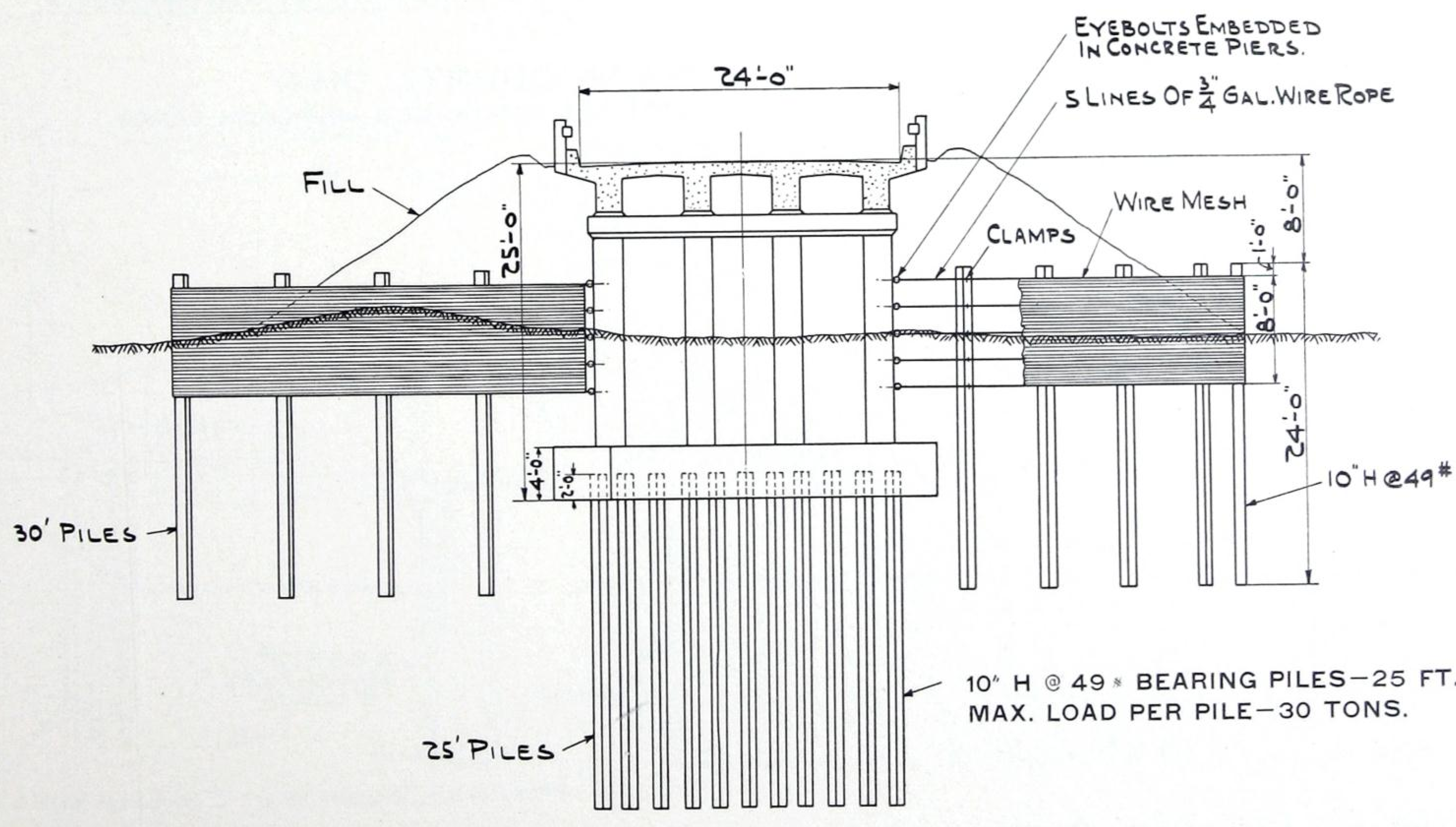


FOUNDATION PLAN
ALL PILES 10" H @ 49#



77 PILES, 10" H 49#
MAX. LOAD PER PILE 25 TO 30 TONS.

ELEVATION

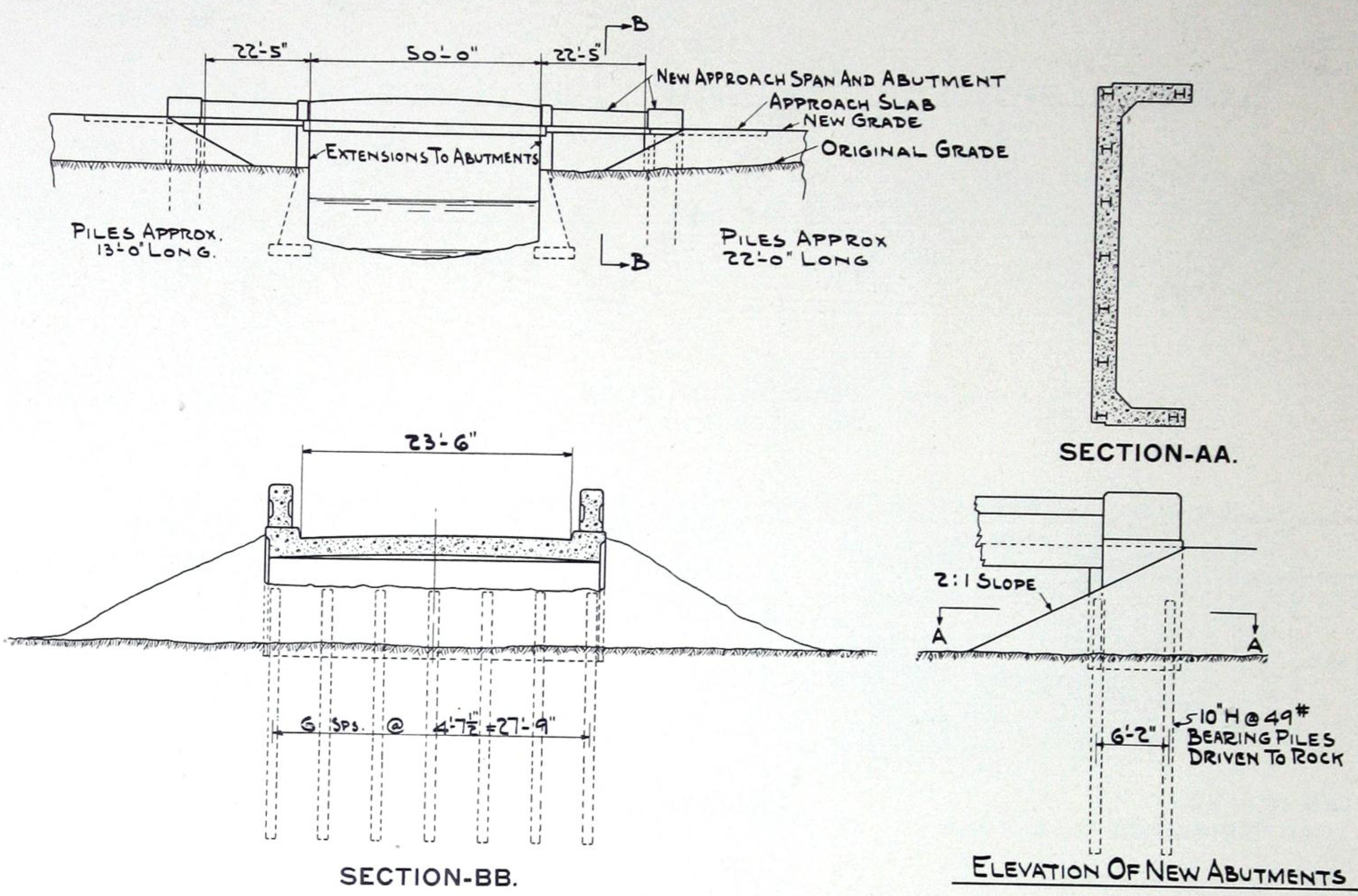


10" H @ 49# BEARING PILES—25 FT. LONG.
MAX. LOAD PER PILE—30 TONS.

SECTION-AA. SHOWING PIER AND BANK PROTECTION

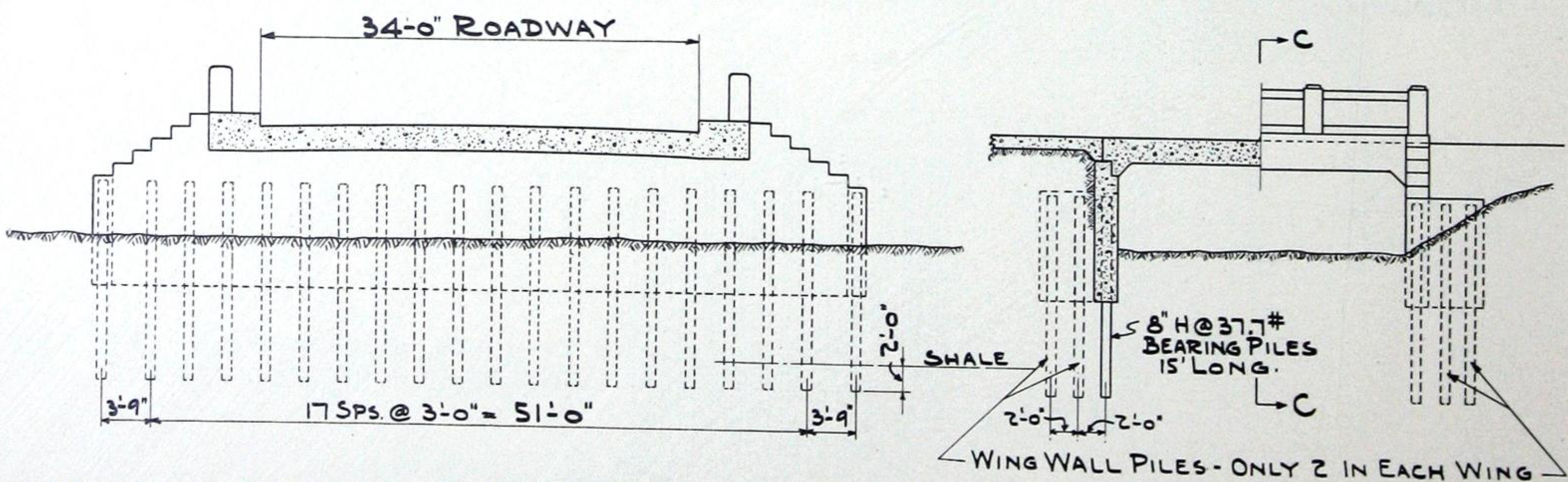
HIGHWAY BRIDGE ACROSS COYOTE CREEK, VENTURA COUNTY, CALIFORNIA

DESIGNED BY
DIVISION OF HIGHWAYS
DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA.



BRIDGE OVER PERRY RUN, MORGAN COUNTY, OHIO

THIS BRIDGE WAS RAISED BY BUILDING UP THE ABUTMENTS AND ADDING NEW APPROACH SPANS.



BRIDGE No. ER-6-167 OVER STREAM IN ERIE COUNTY, OHIO

SEC. HURON WEST

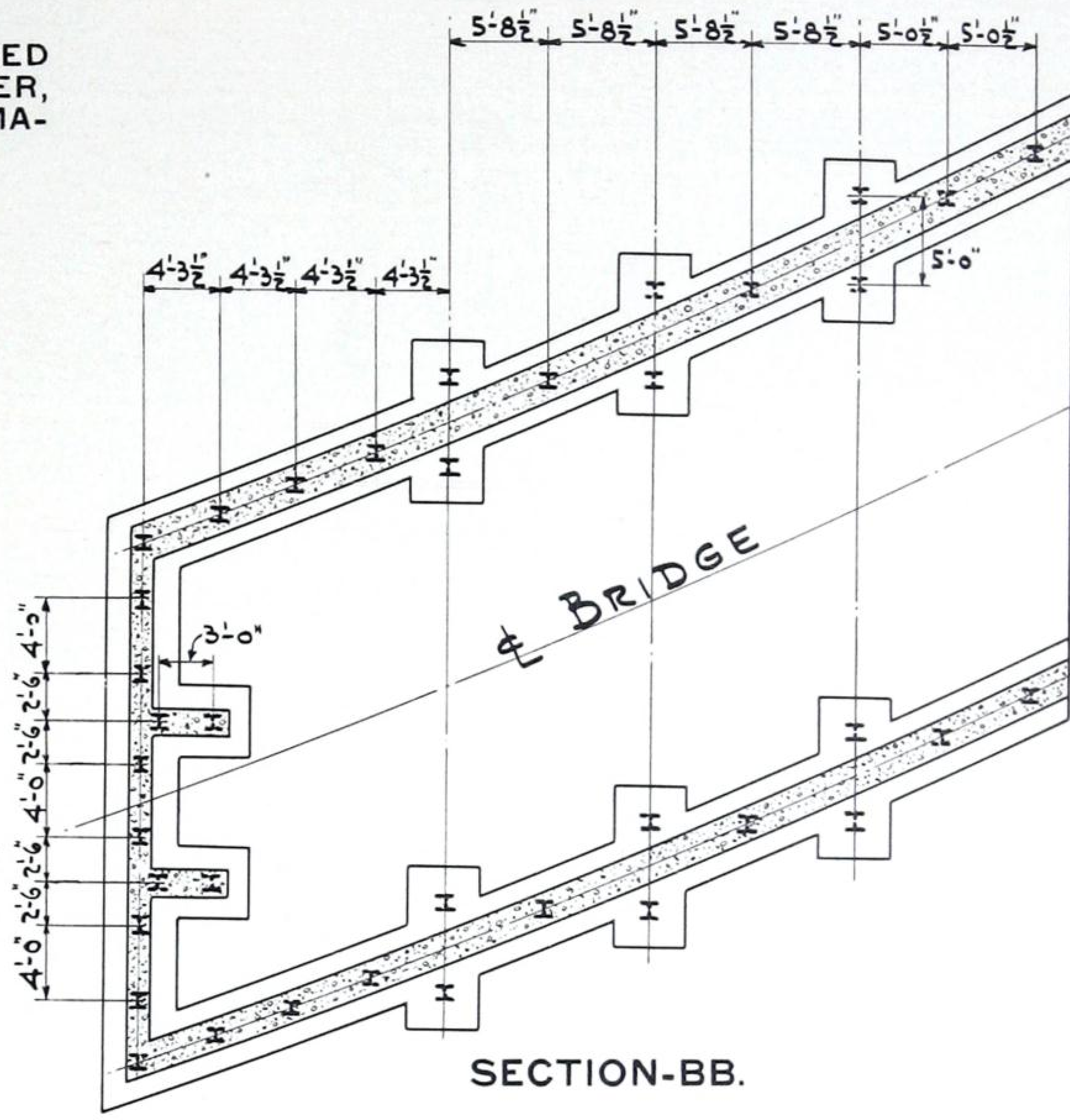
48 PILES 8"H 37.7# x 15' DRIVEN AN AVERAGE OF 11' DOWN INTO SLATE BY 3000 LB. GRAVITY HAMMER. SUBSOIL IS MOSTLY MUCK EXCEPT LAST 2' ABOVE THE SLATE IS SHALE.

DESIGNED BY
BUREAU OF BRIDGES
DEPARTMENT OF HIGHWAYS
STATE OF OHIO

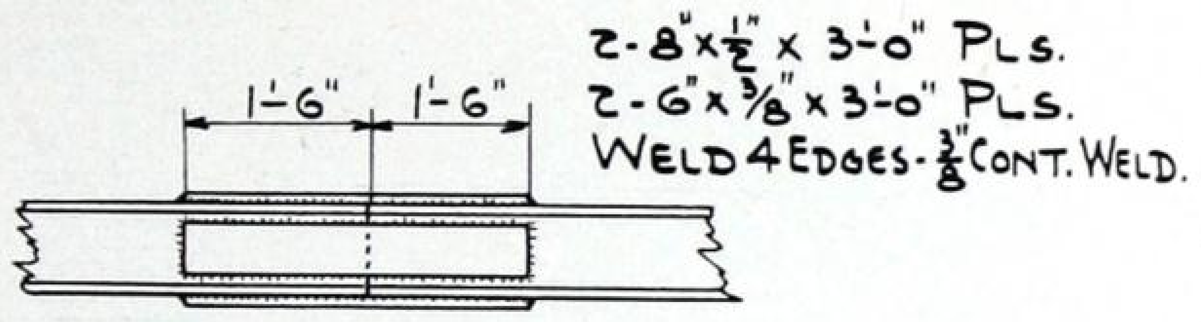
38 PILES, 8" H 40*

SPECIFICATIONS REQUIRED DRIVING OF 2 SPLICED 60' TEST PILES AT POINTS DIRECTED BY ENGINEER, WITH PILES LATER TO BECOME PART OF PERMANENT CONSTRUCTION.

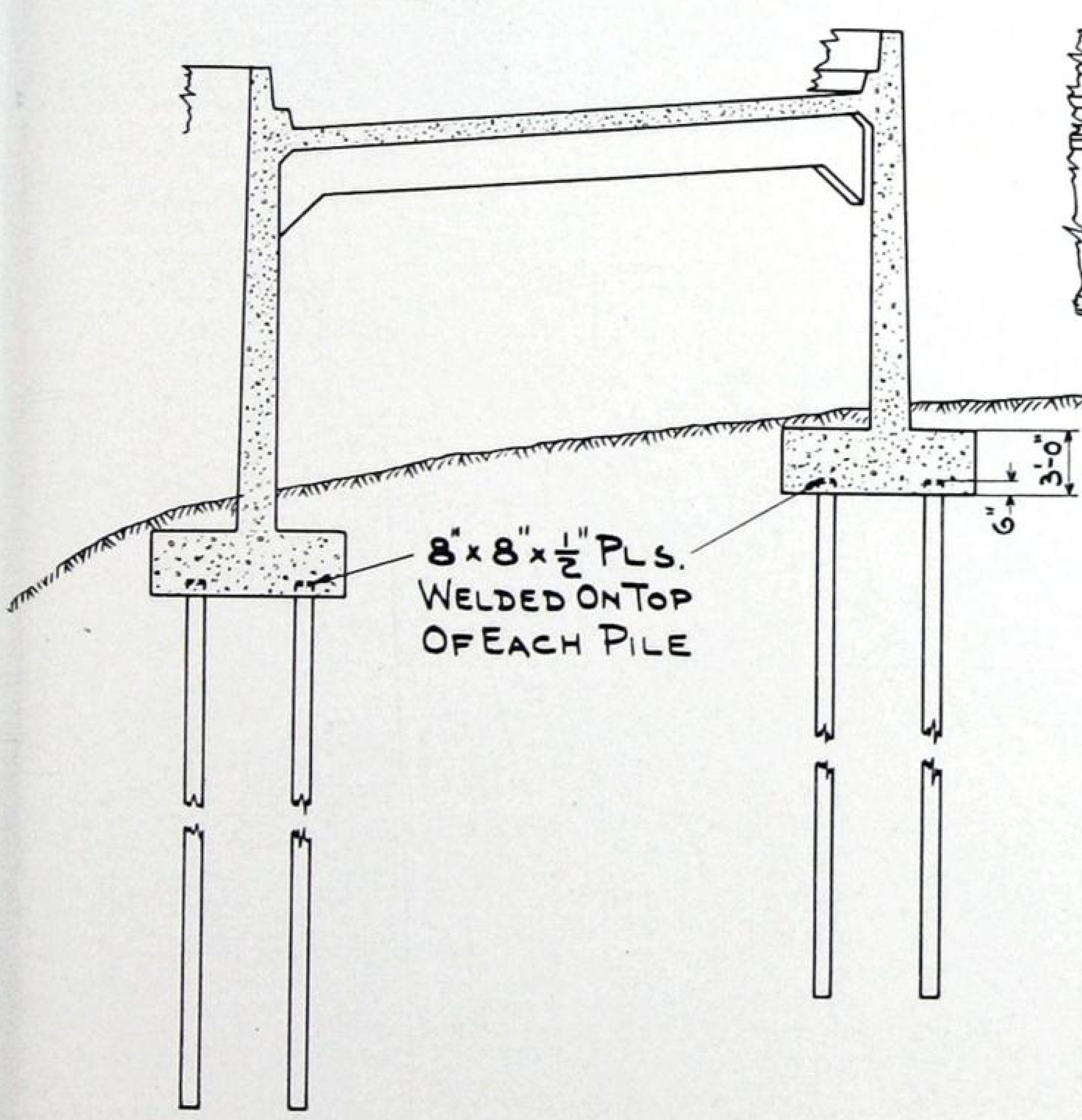
LOAD ON EACH PILE, ABOUT 30 TONS BY ENGINEERING—NEWS FORMULA.



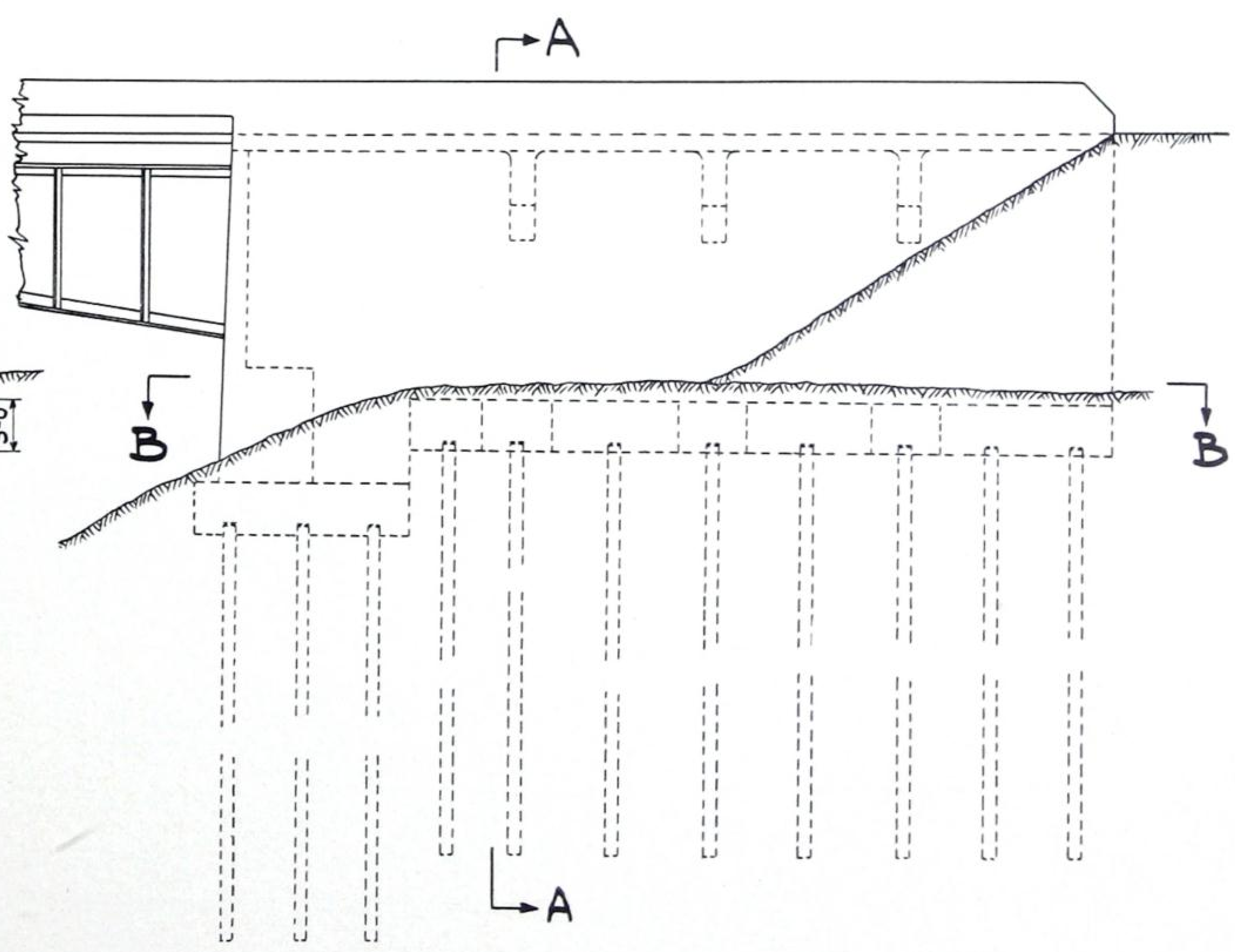
SECTION-BB.



DETAIL OF PILE SPLICE

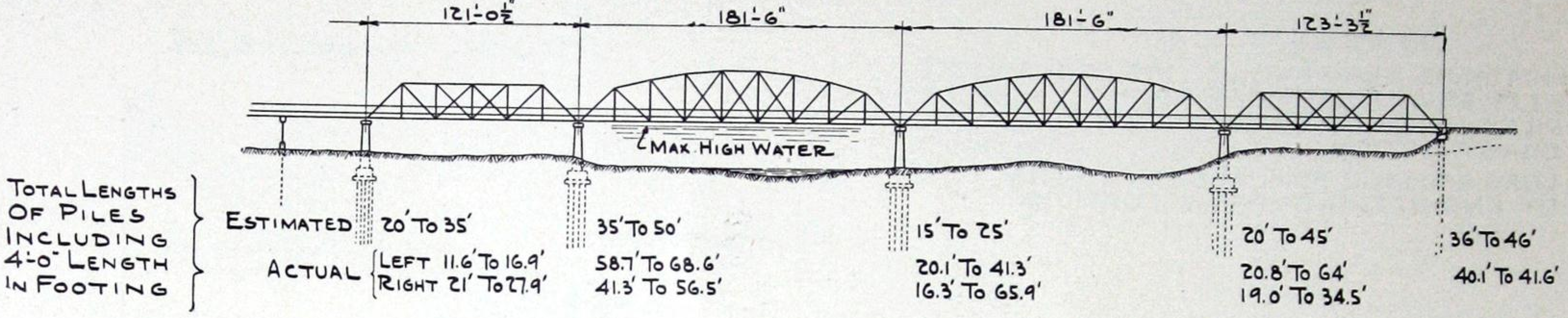


SECTION-AA.

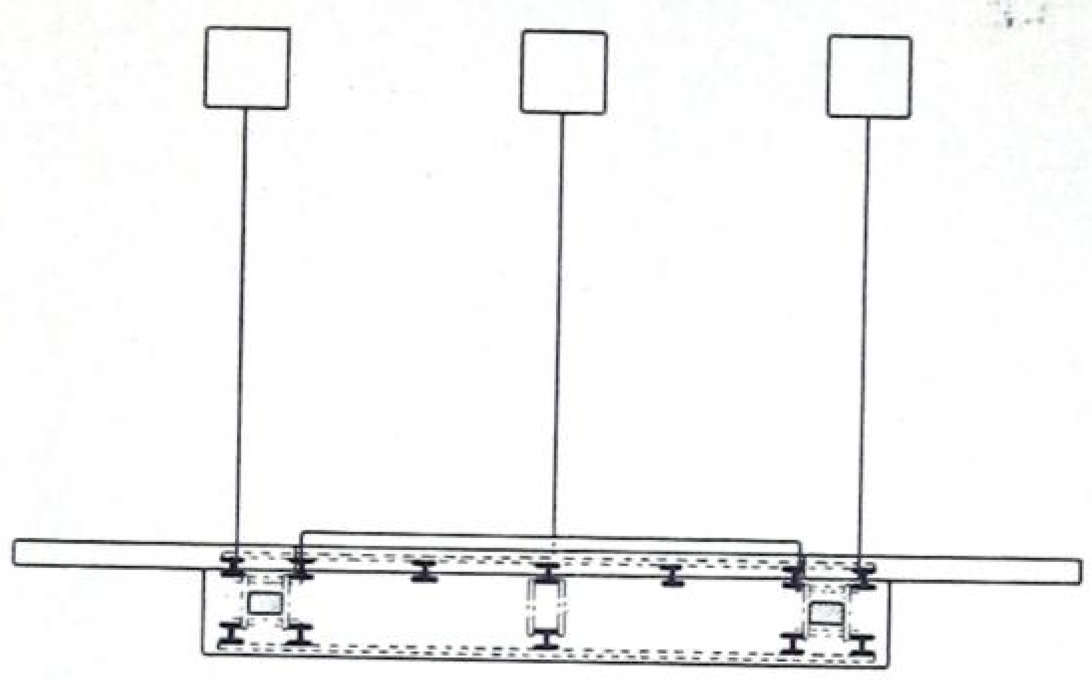


ABUTMENT FOR BRIDGE ACROSS SOUTH FORK OF EEL RIVER, SMITH POINT, HUMBOLT COUNTY, CALIFORNIA.

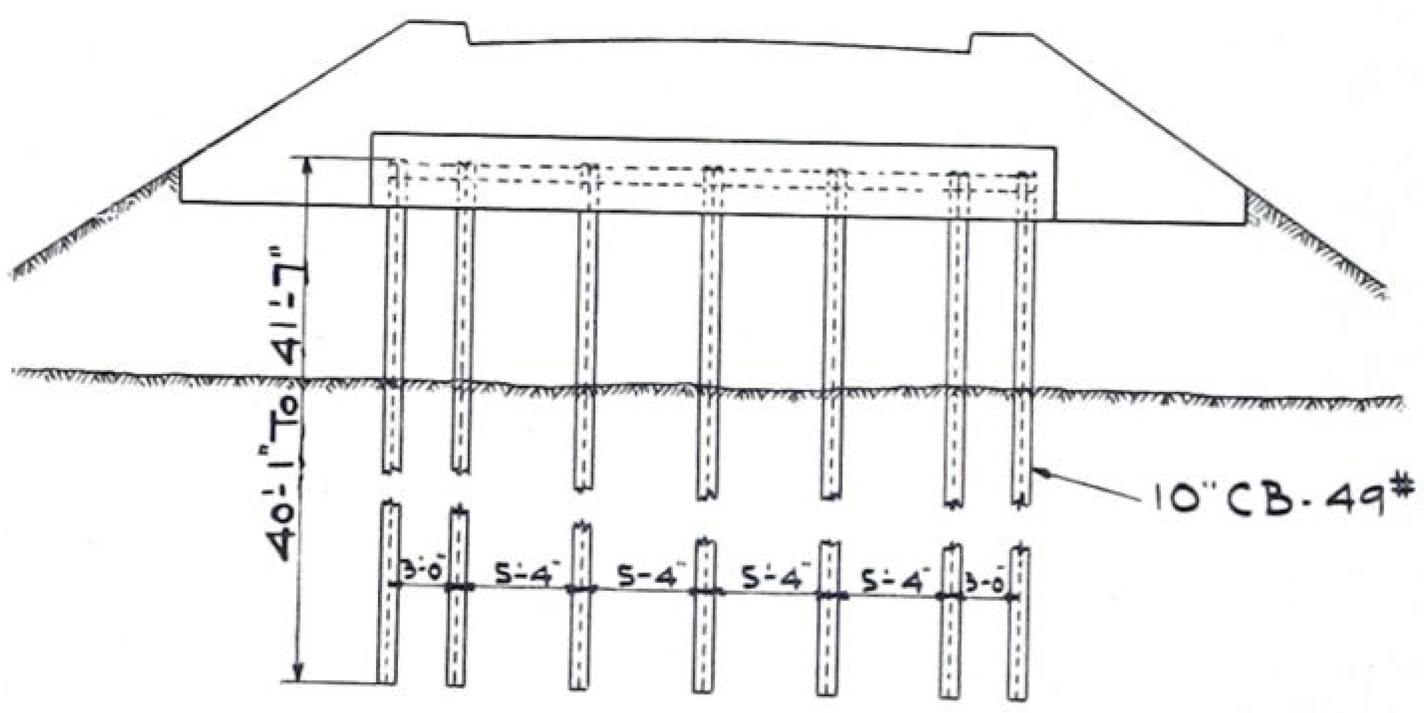
DESIGNED BY
DIVISION OF HIGHWAYS
DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA.



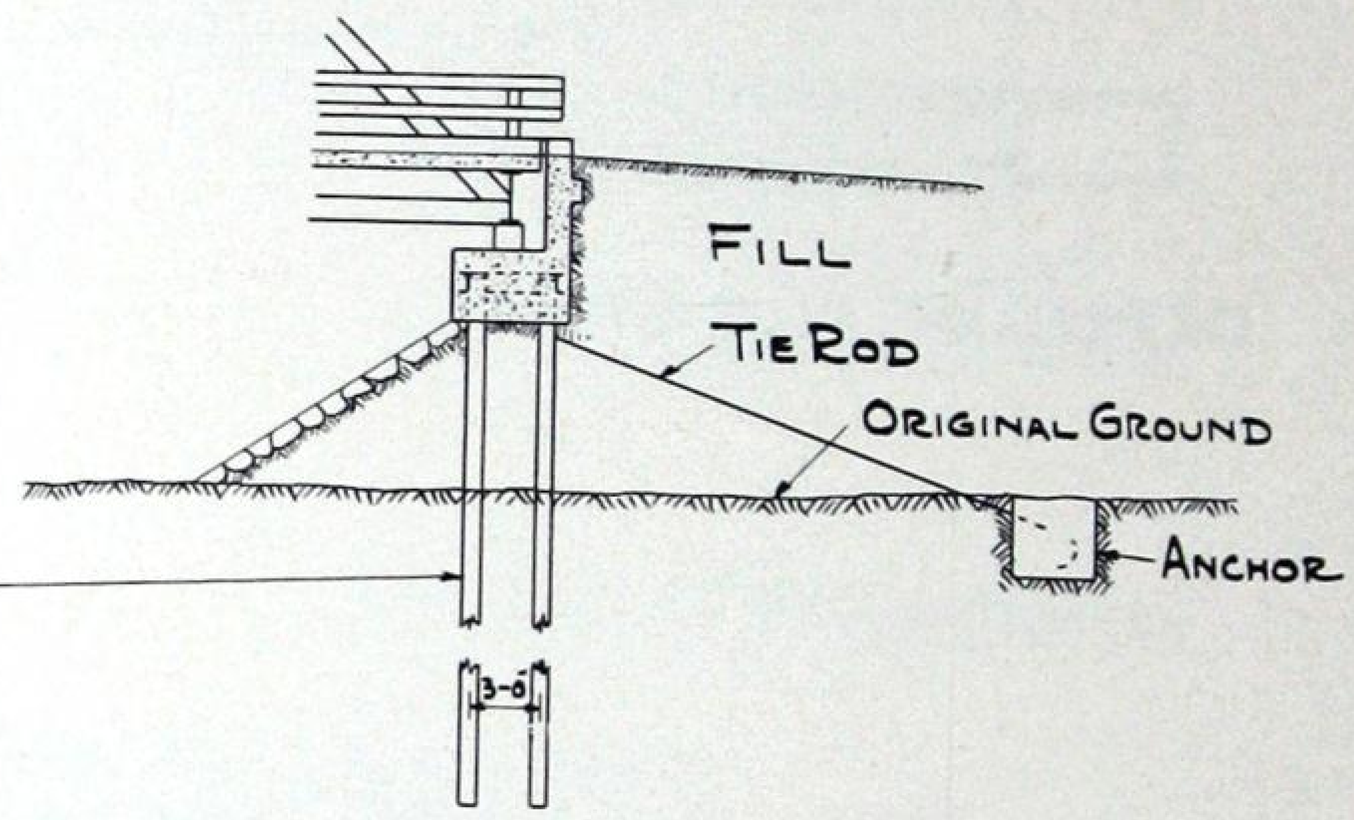
100 PILES, 10" CB 49 # 16'-4" TO 64'-0"—ONE OR TWO SPLICES PER PILE. DRIVEN FROM 11.6' TO 41.6' THROUGH SANDY LOAM, SAND AND GRAVEL, BOULDERS AND LEDGES OF SOFT BROWN LIMESTONE TO RESISTANCE OF 0" TO ½" PER 100 BLOWS OF #9-B2 McKIERNAN-TERRY HAMMER. ON 16 OF THE SHORTER PILES AN ATTEMPT WAS MADE TO SECURE GREATER PENETRATIONS WITH A VULCAN HAMMER. IT GAVE PENETRATIONS RANGING FROM 0" TO ¾" PER 100 BLOWS AT END OF DRIVING, WHICH DID NOT REPRESENT A MATERIAL INCREASE. THE SHORTER PILES EVIDENTLY RESTED ON LARGE BOULDERS AS ADJACENT PILES WERE DRIVEN CONSIDERABLY DEEPER



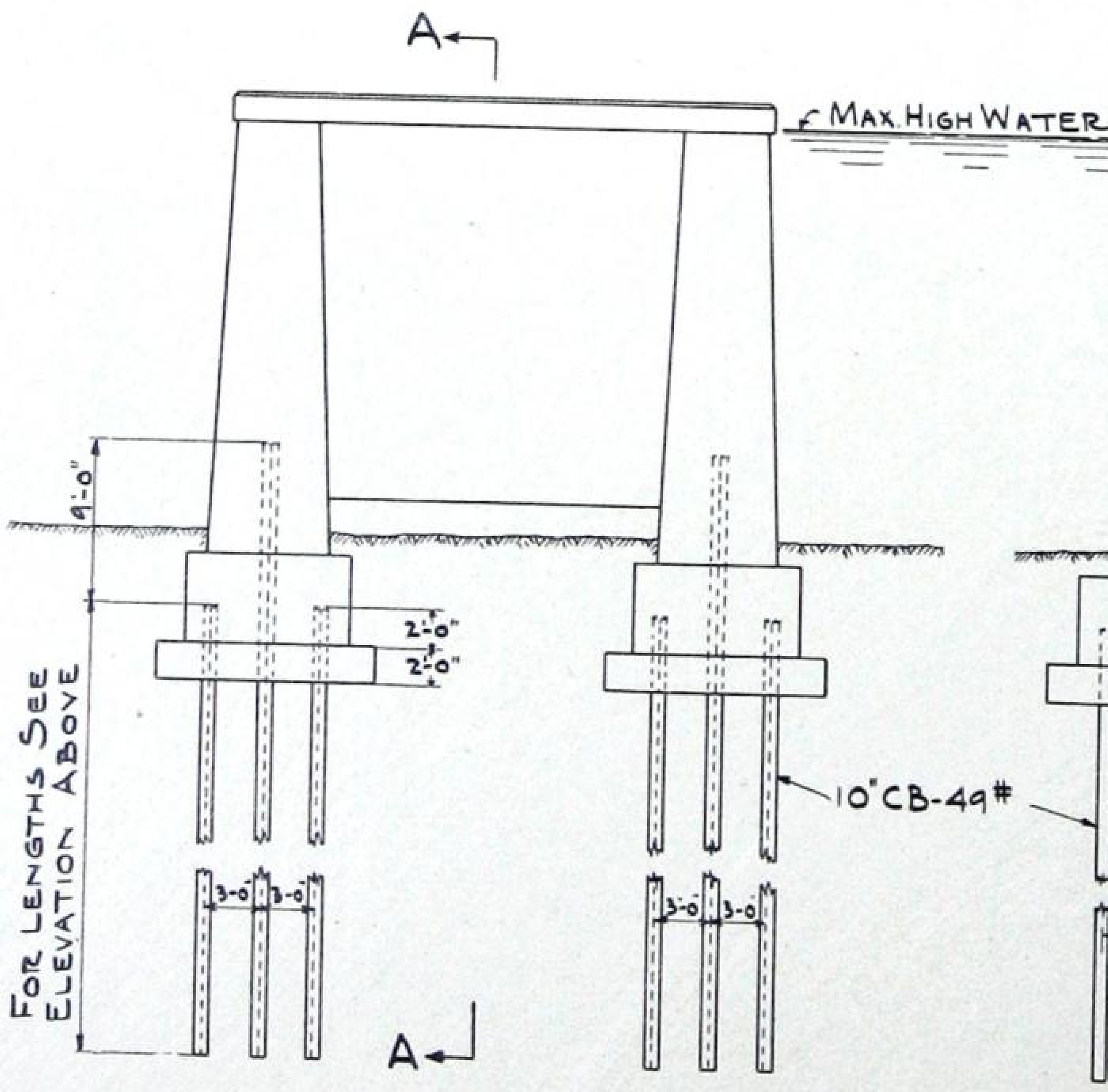
PLAN OF ABUTMENT



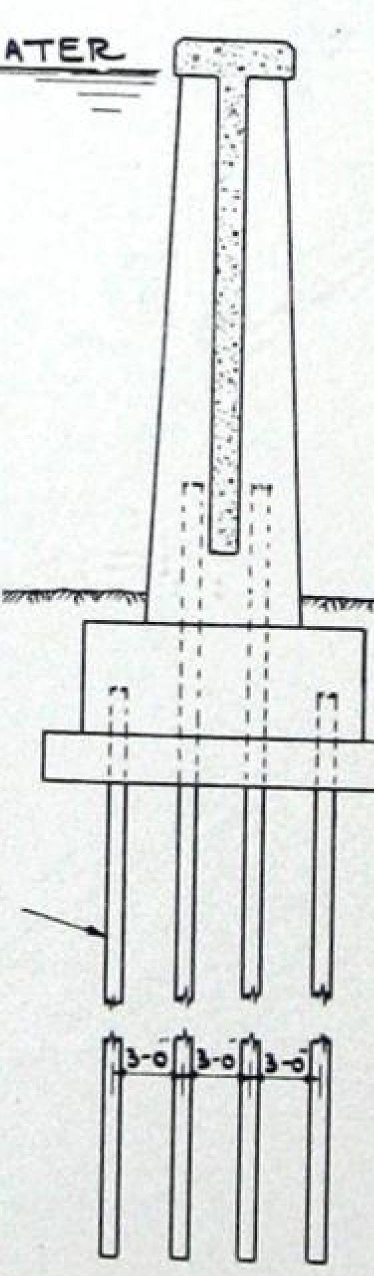
ELEVATION



SECTION THROUGH ABUTMENT



ELEVATION OF PIER



SECTION-AA.

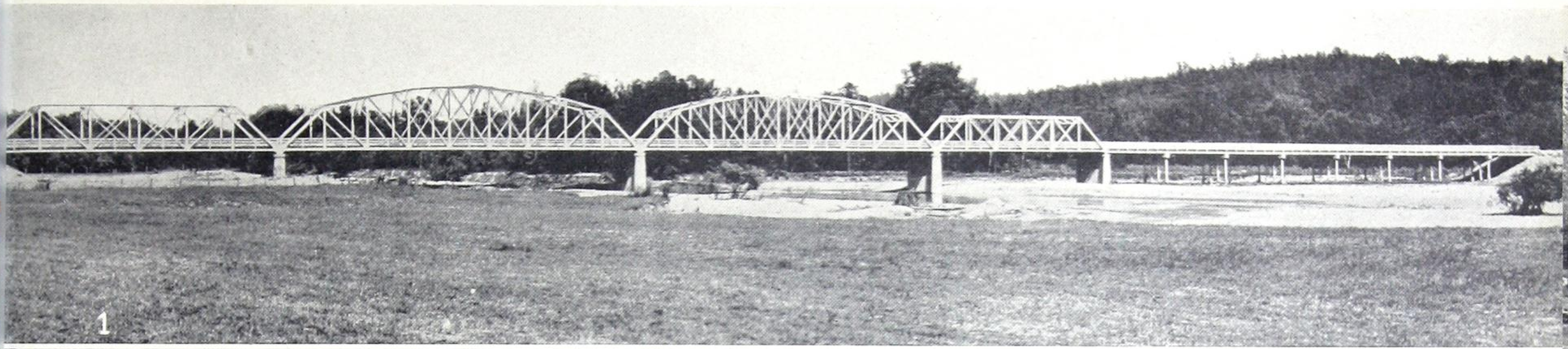
MAIN PIERS AND ABUTMENT BRIDGE OVER BLACK RIVER, LEEPER, WAYNE COUNTY, MISSOURI

SEE PRECEDING SHEET OF DRAWINGS FOR ADDITIONAL DETAILS ILLUSTRATING PILES UNDER MAIN PIERS.

DESIGNED BY
MISSOURI STATE
HIGHWAY DEPARTMENT

SEE PHOTOGRAPHS ON OPPOSITE PAGE

1. GENERAL VIEW OF BRIDGE.
2. ABUTMENT END OF TRESTLE BENT VIADUCT CONSTRUCTION. NOTE TIE RODS IN POSITION AS INDICATED ON DRAWING.
3. ABUTMENT END OF TRUSS SPAN BEFORE GRADING AND PLACING OF FILL.
4. GENERAL VIEW OF TRESTLE BENT CONSTRUCTION.



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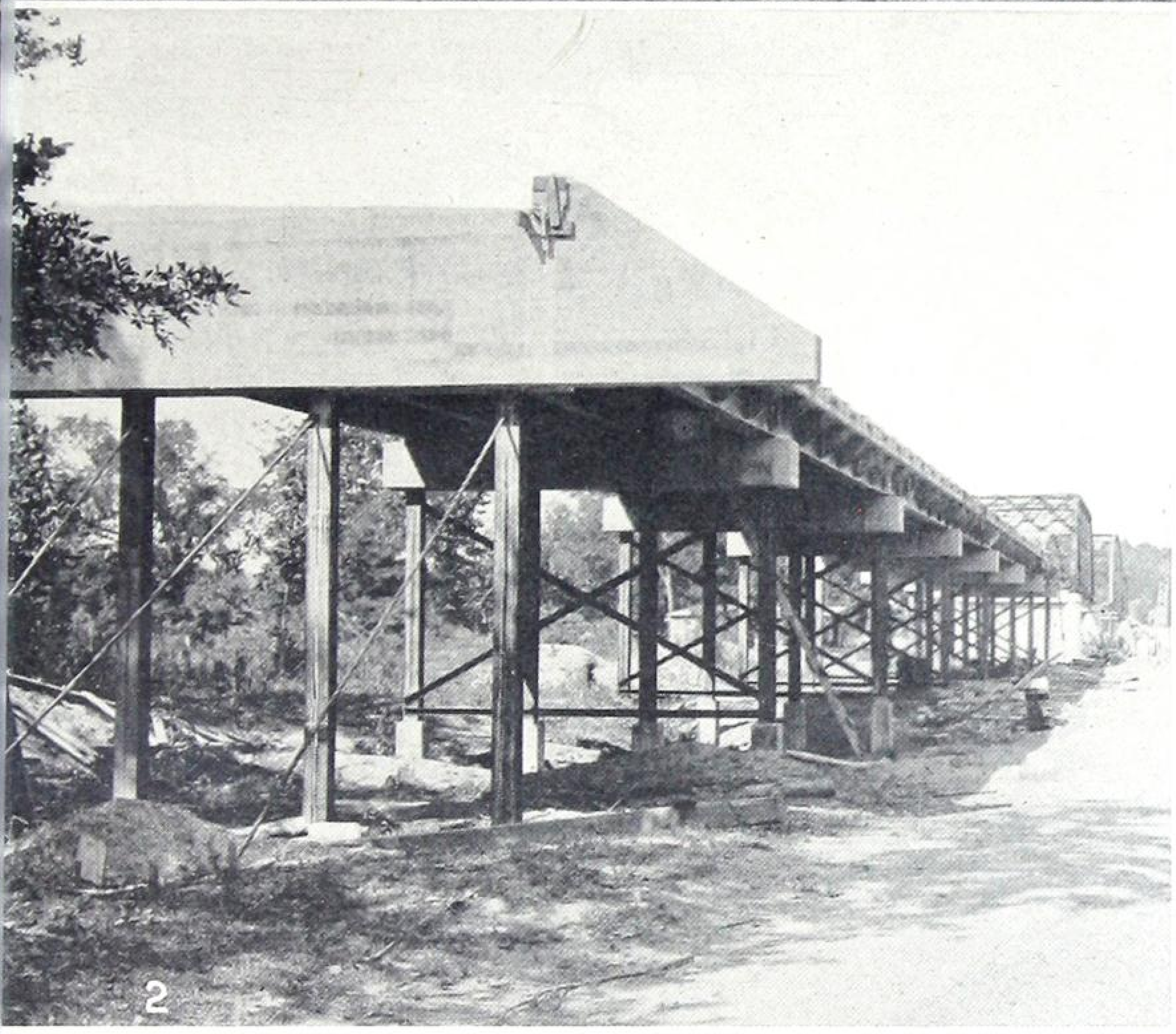

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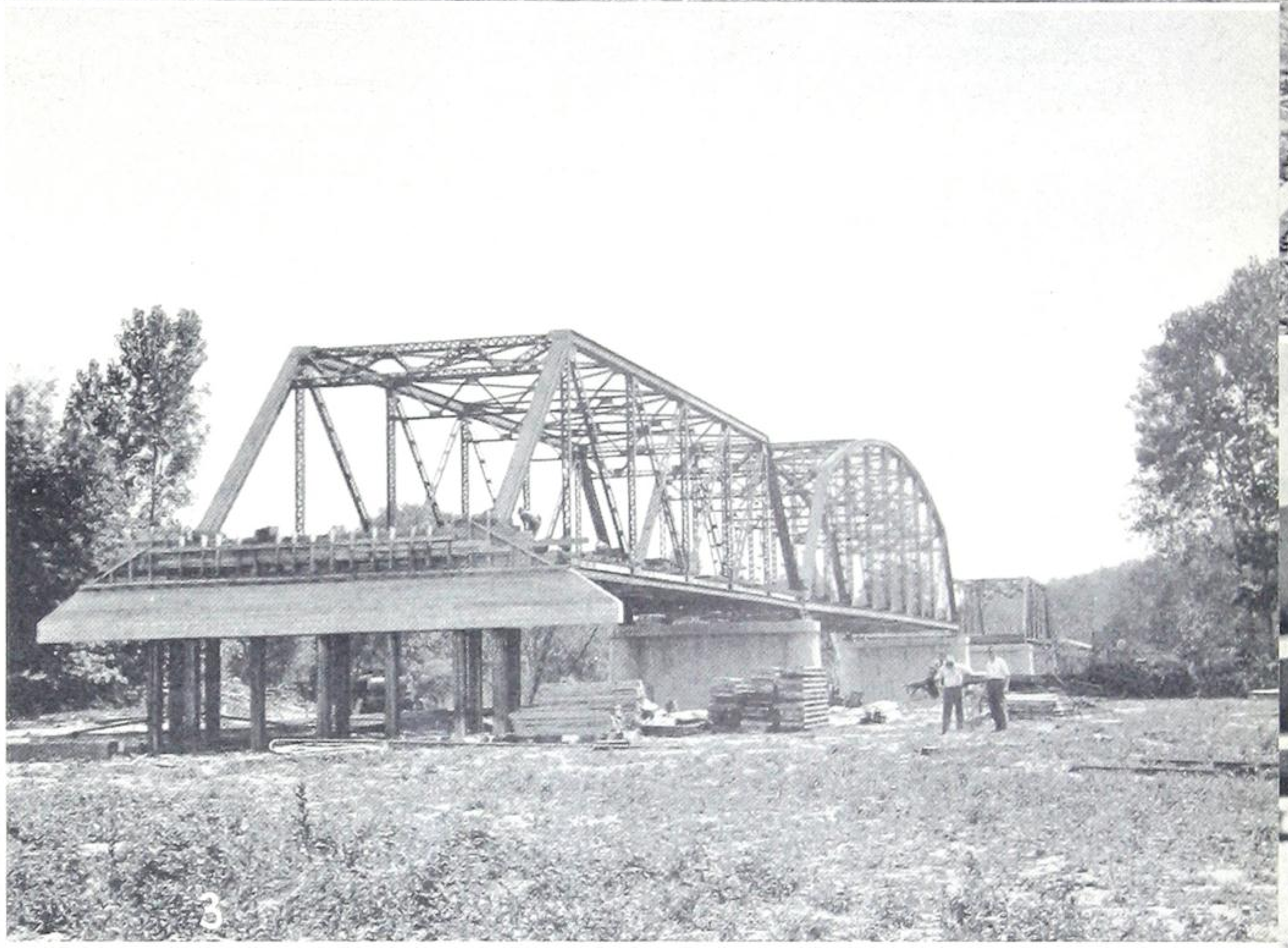

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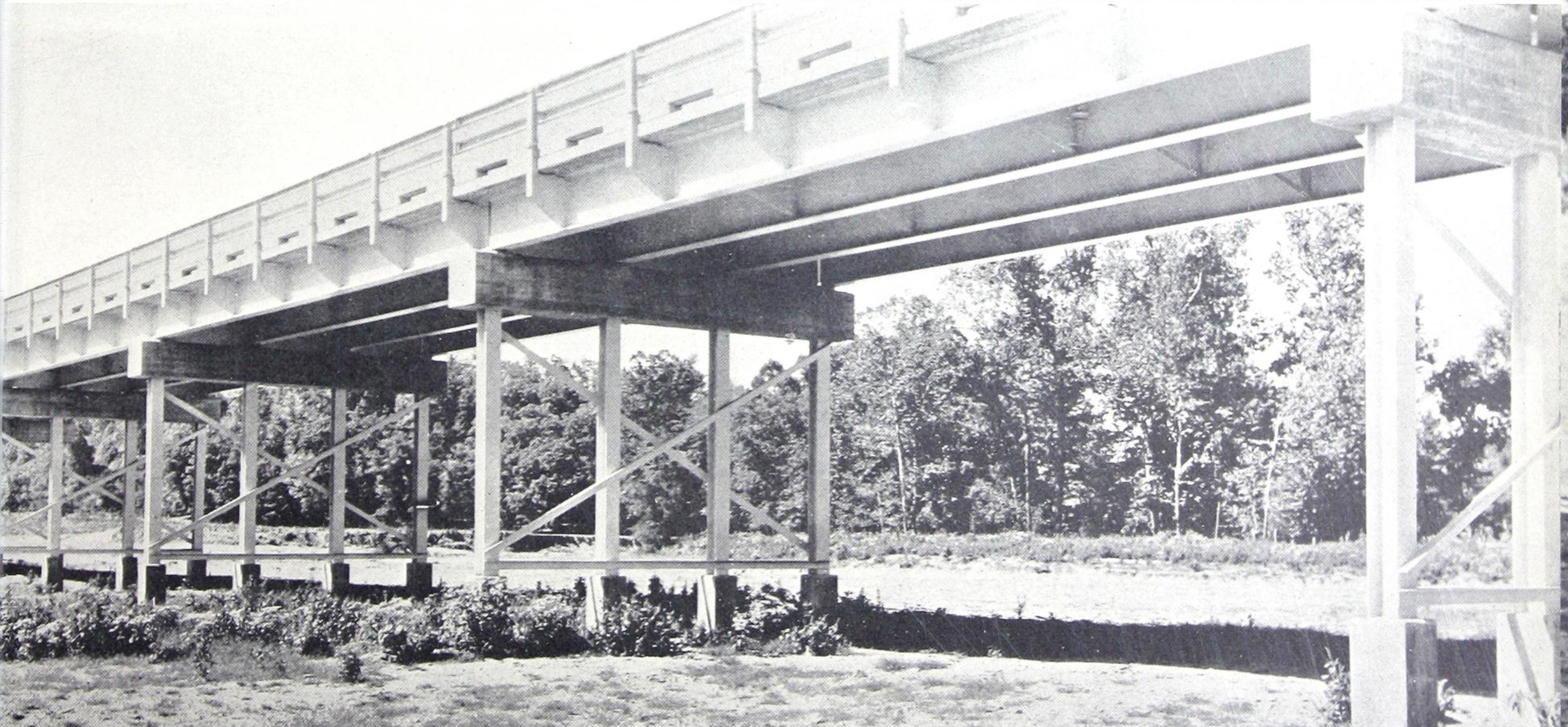

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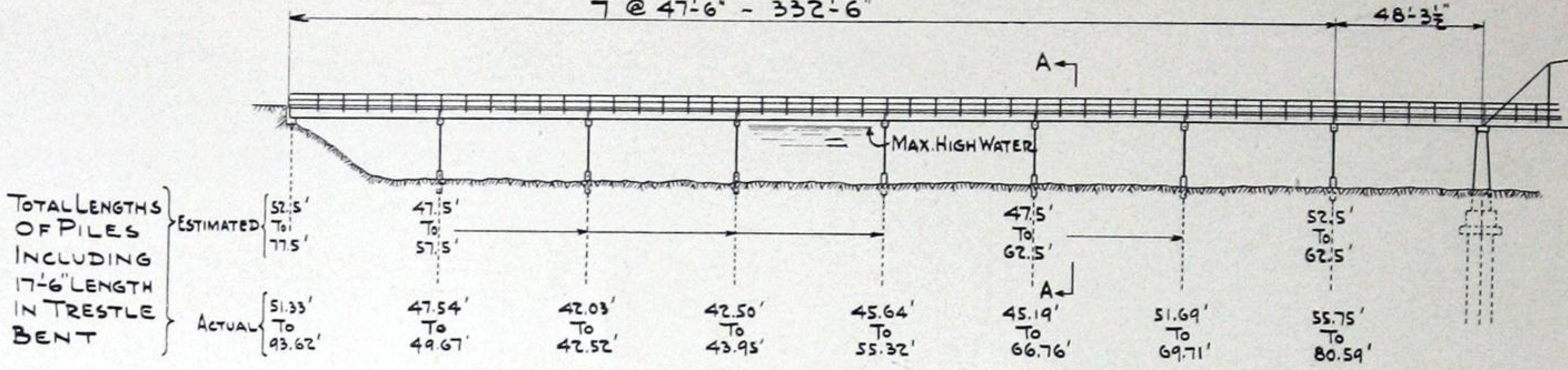
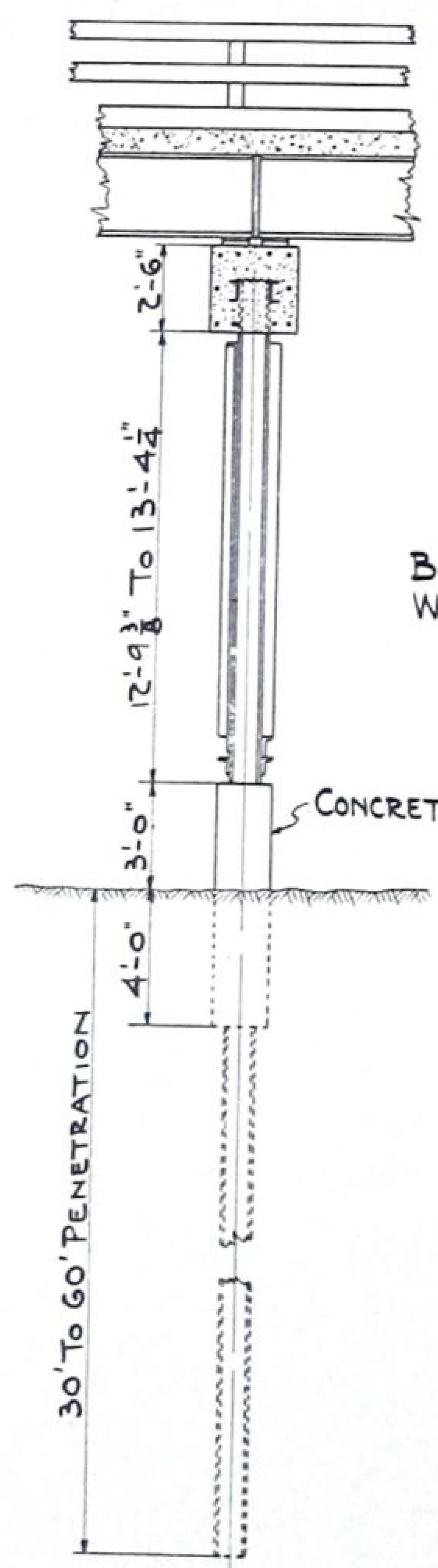
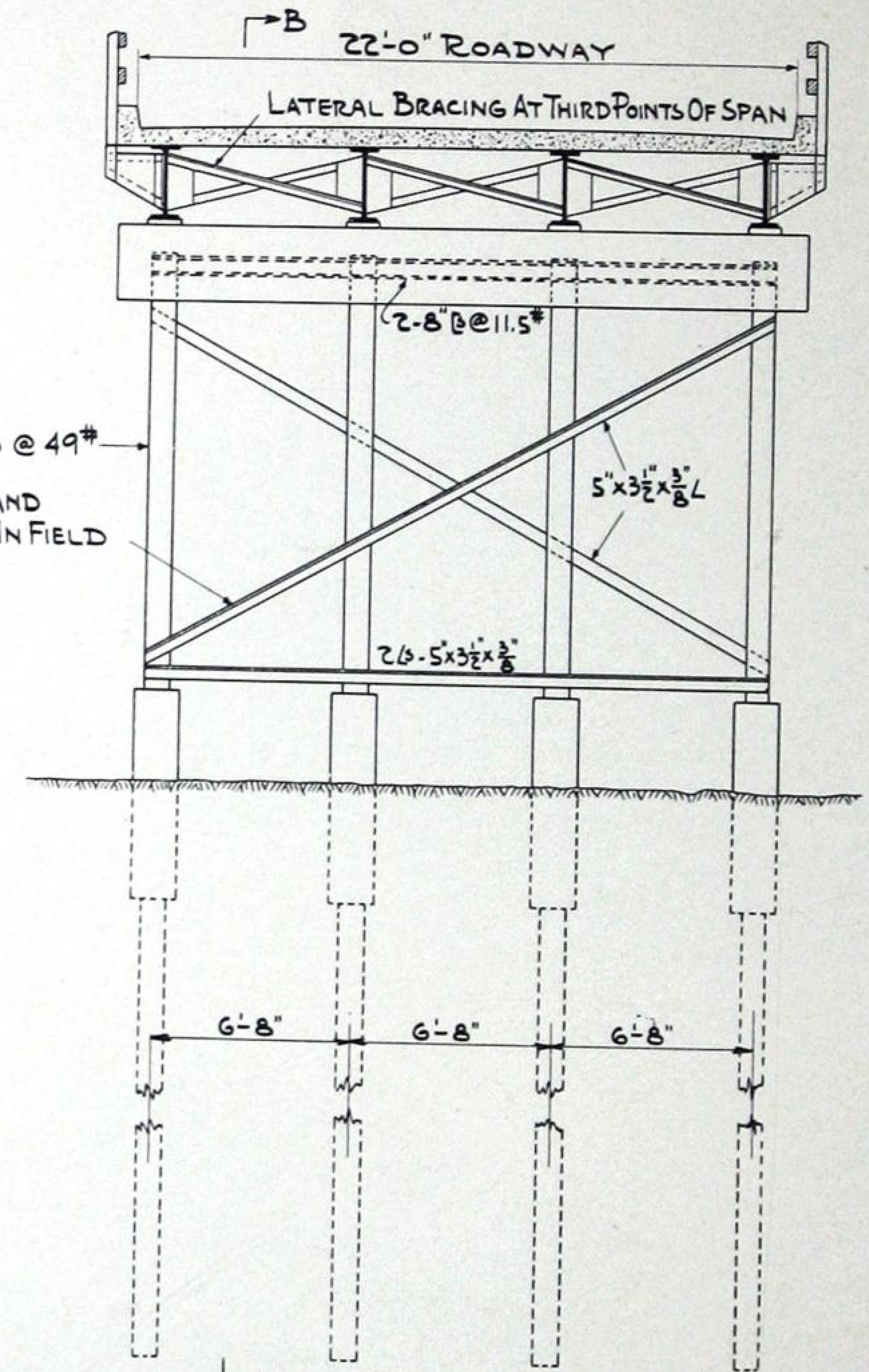


32 PILES, 10" CB 49# — ONE TO THREE SPLICES PER PILE

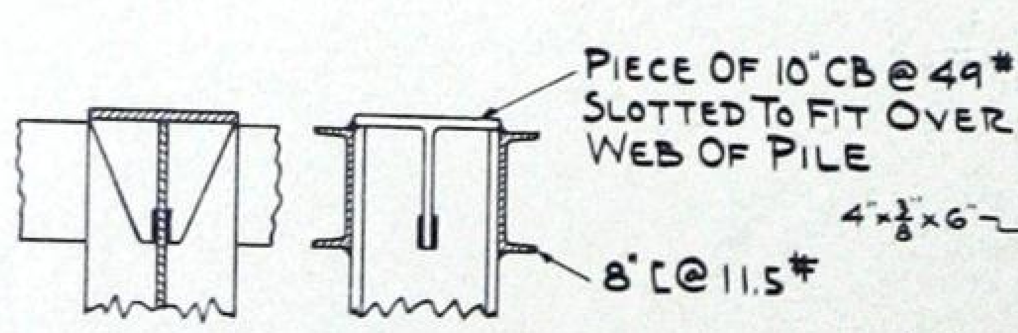
DRIVEN THROUGH SANDY LOAM, SAND AND GRAVEL AND LEDGES OF SOFT BROWN LIMESTONE INTO ROCK TO RESISTANCE OF 0" TO ½" PER HUNDRED BLOWS OF #9B2 McKIERNAN-TERRY HAMMER. TOTAL SOIL PENETRATIONS RANGED FROM 24'-6" TO 63'-1" UNDER BENTS AND 49'-4" TO 91'-7" UNDER ABUTMENT



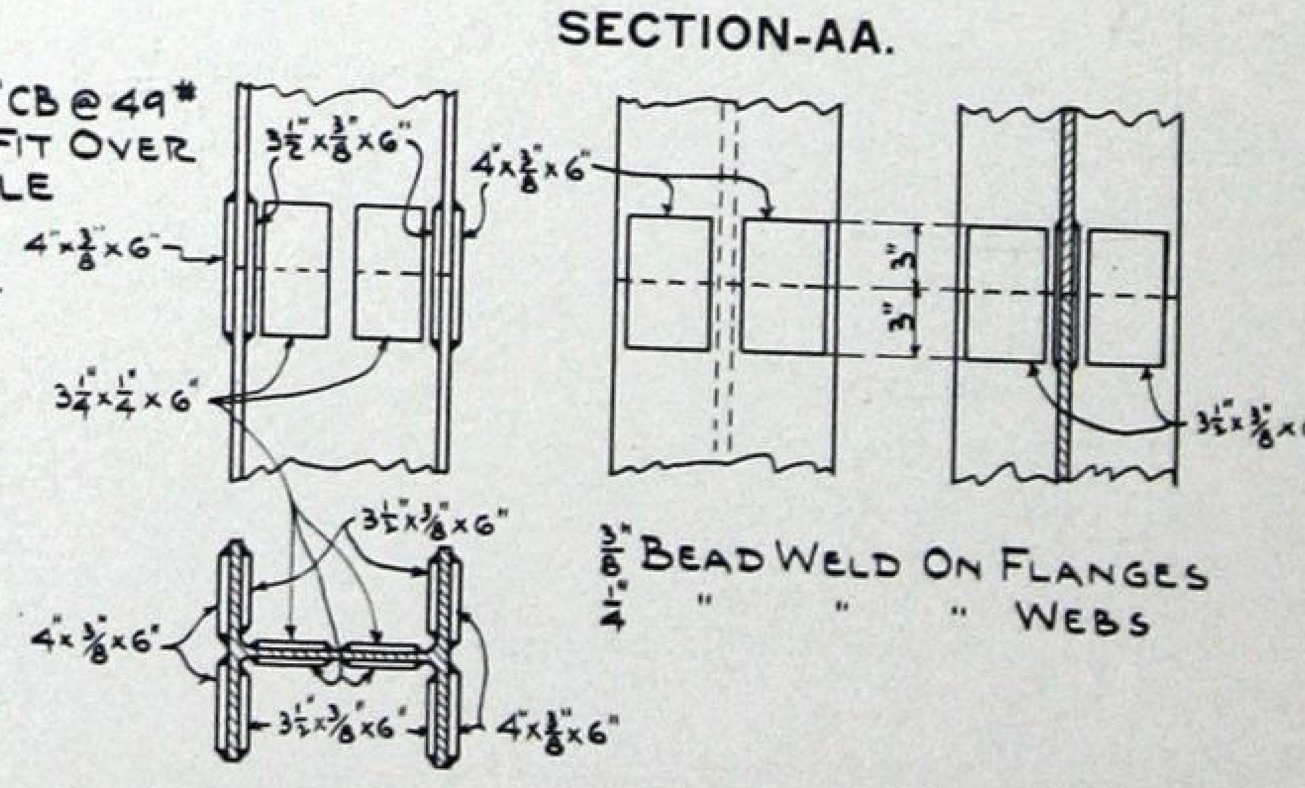
SECTION-BB.



SECTION-AA.



DETAIL OF PILE CAP



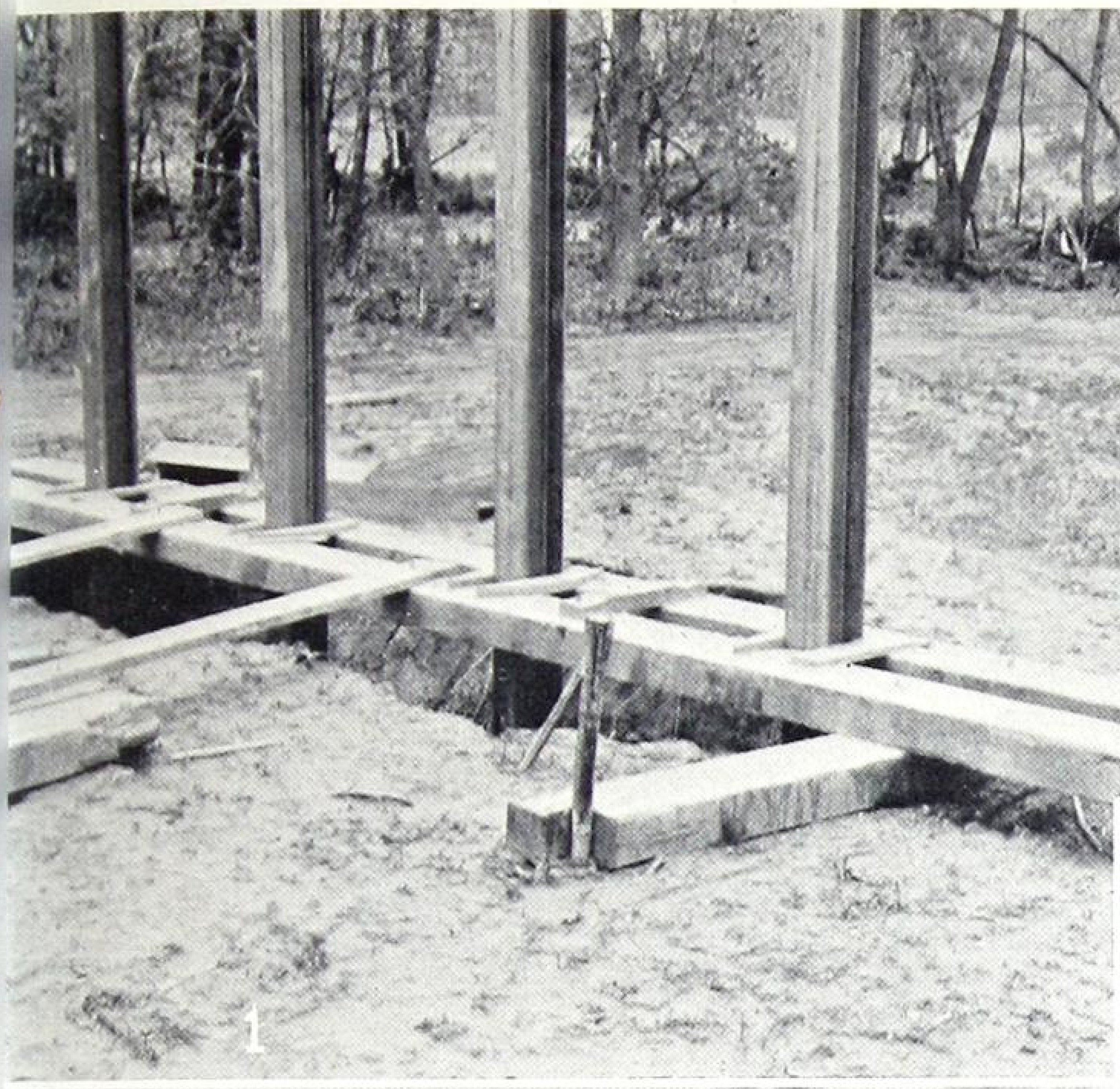
DETAIL OF PILE SPLICES

TRESTLE BENTS
BRIDGE OVER BLACK RIVER, LEEPER
WAYNE COUNTY—MISSOURI

SEE NEXT SHEET OF DRAWINGS FOR ADDITIONAL DETAILS ILLUSTRATING PILES UNDER MAIN PIERS.

SEE PHOTOGRAPHS ON OPPOSITE PAGE

1. PILES SET UP IN SIMPLE GUIDE FRAMES, PREPARATORY TO DRIVING.
2. PILES IN FOREGROUND DRIVEN TO REQUIRED RESISTANCE. NOTE THE VARYING PENETRATION AS INDICATED BY THE DIFFERENCE IN LENGTH OF THE PILES ABOVE GROUND.
3. PILES CUT OFF TO UNIFORM ELEVATION, CHANNEL CAPS APPLIED AND HELD WITH CLAMPS WHILE BEING WELDED.
4. COMPLETED TRESTLE BENT. NOTE THE DIAGONAL AND HORIZONTAL ANGLE BRACING; ALSO THE CONCRETE PROTECTION AROUND PILES ABOVE GROUND LINE.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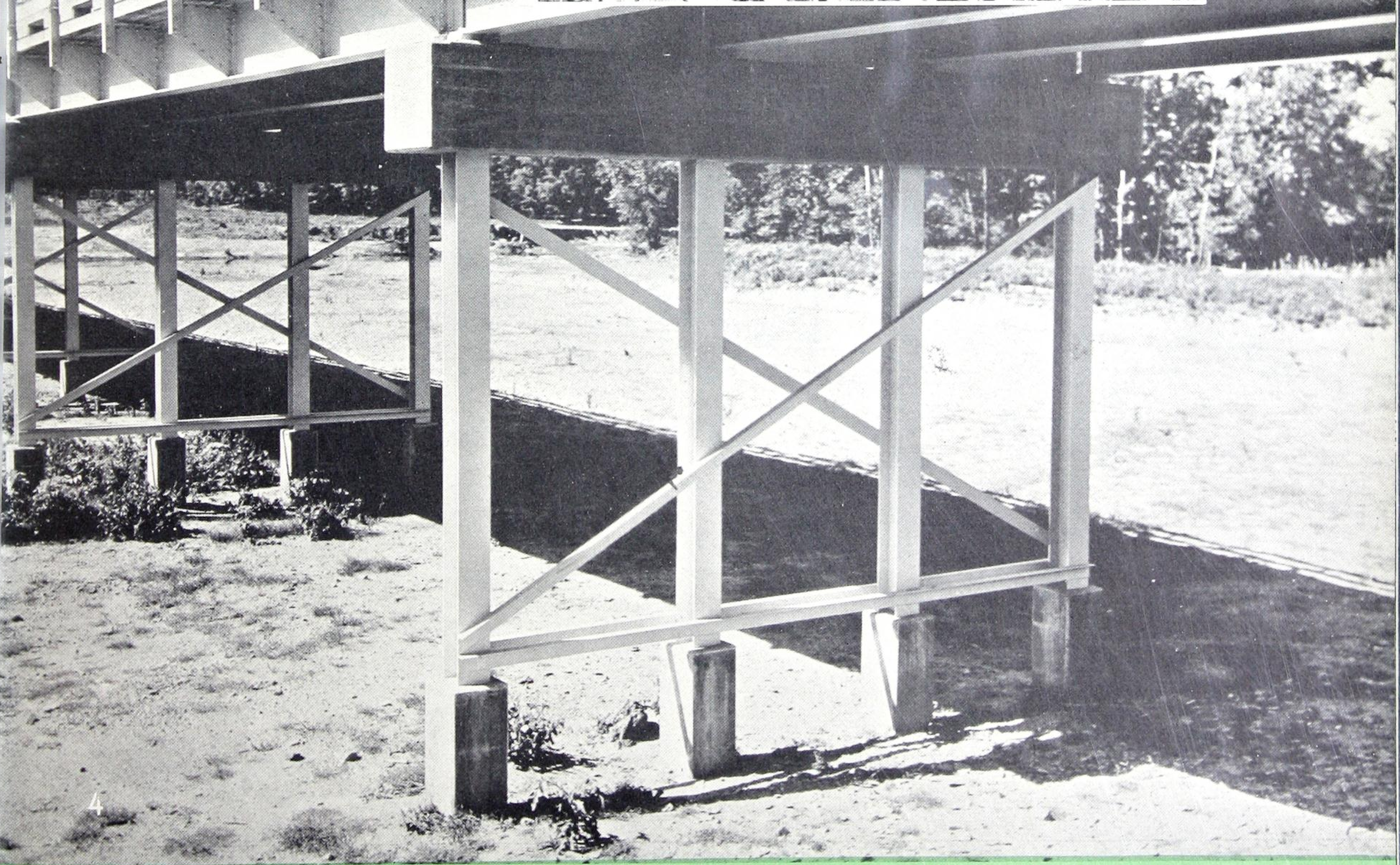
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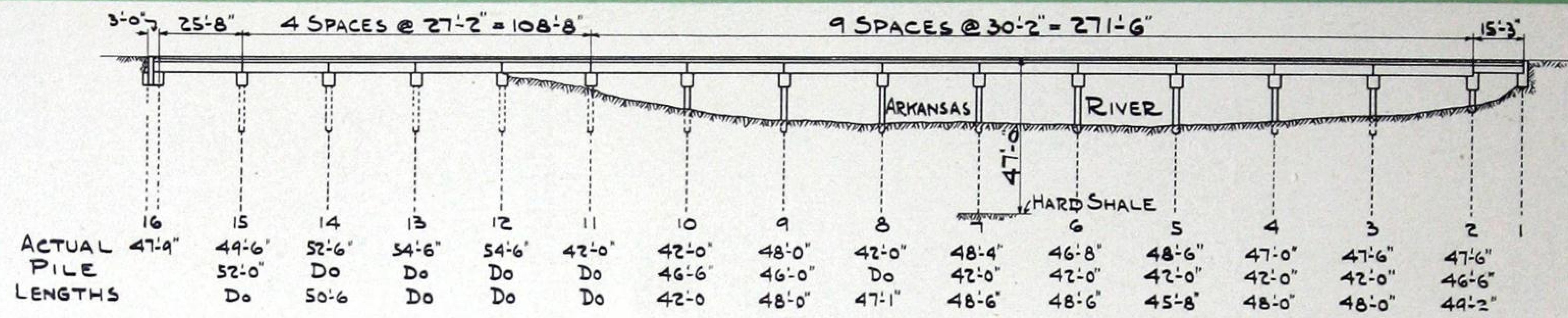
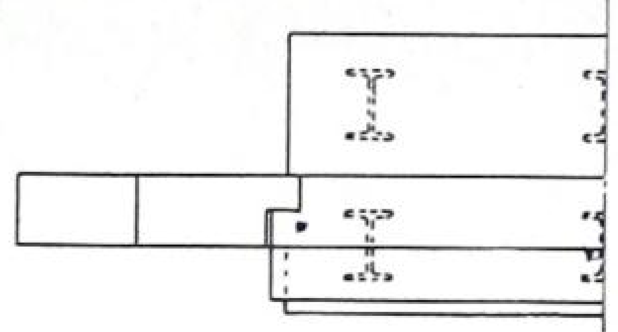
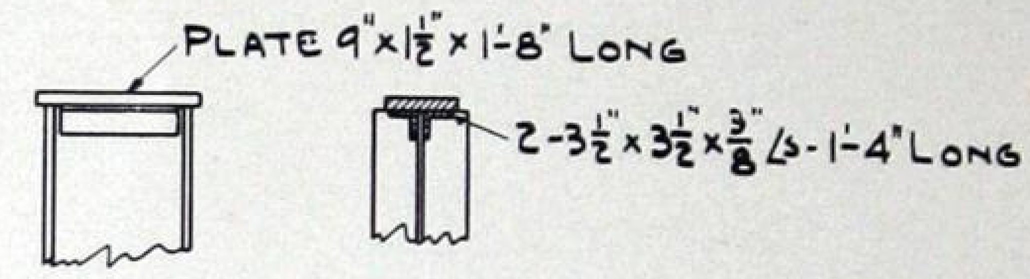


ELEVATION OF BRIDGE

51 PILES, 18" CB 71#

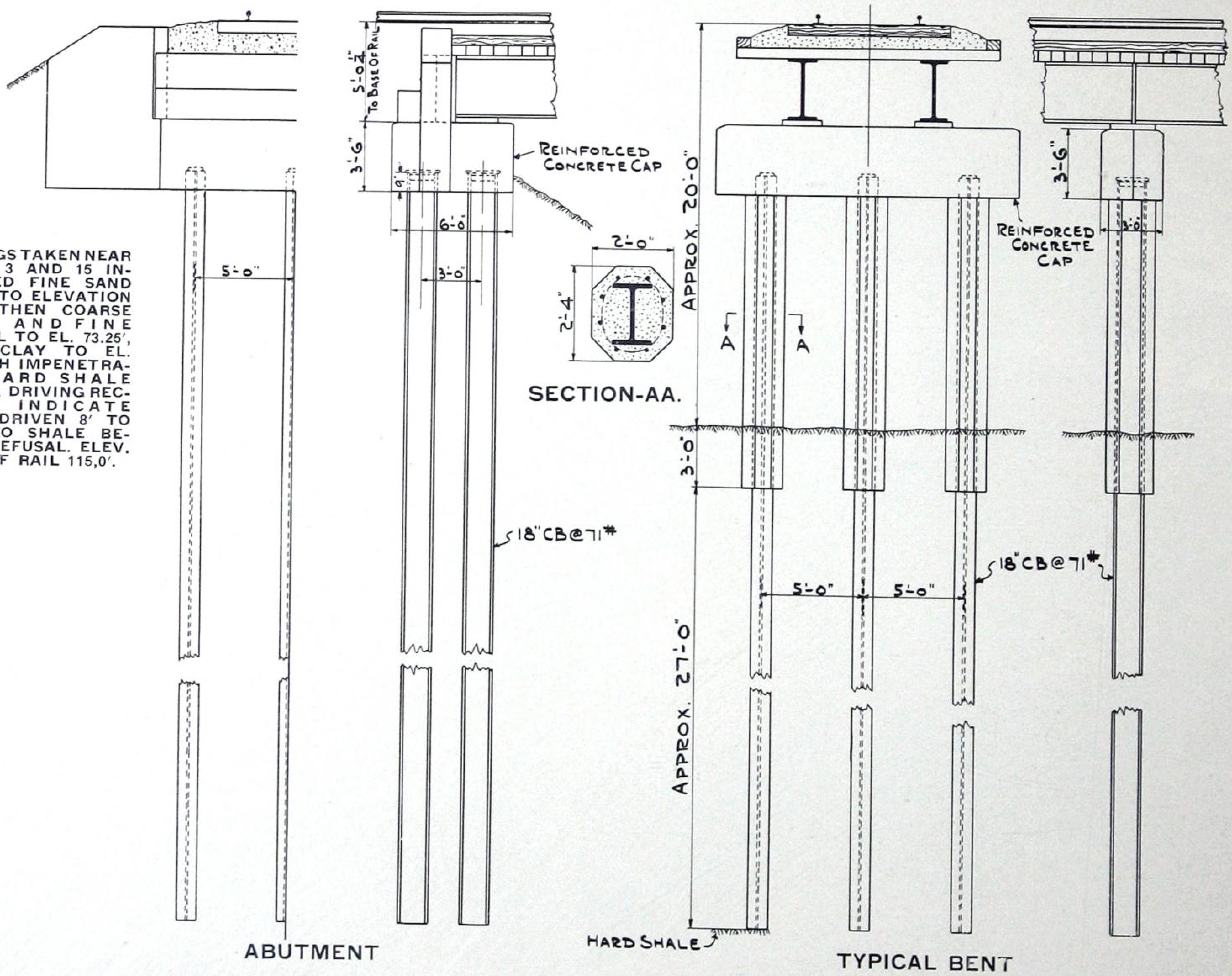


MATERIAL ORDERED IN 42' LENGTHS. SEE ELEVATION ABOVE FOR ACTUAL LENGTHS DRIVEN. BETWEEN POINTS WHERE BORINGS WERE TAKEN SOLID ROCK WAS FOUND TO BE FROM 6' TO 10' LOWER THAN INDICATED BY THE TWO BORINGS NECESSITATING THE SPLICING ON OF AS MUCH AS 12-6' ONTO THE ORIGINAL 42'-0" LONG STEEL PILE
VULCAN #1 HAMMER USED.
PILES DRIVEN TO RESISTANCE RANGING FROM 20 BLOWS PER INCH FOR LAST 3 INCHES TO ABSOLUTE REFUSAL



DETAIL OF PILE CAP

BORINGS TAKEN NEAR BENTS 3 AND 15 INDICATED FINE SAND DOWN TO ELEVATION 78.25', THEN COARSE SAND AND FINE GRAVEL TO EL. 73.25', THEN CLAY TO EL. 68' WITH IMPENETRABLE HARD SHALE BELOW. DRIVING RECORDS INDICATE PILES DRIVEN 8' TO 11' INTO SHALE BEFORE REFUSAL. ELEV. BASE OF RAIL 115,0'.



ABUTMENT

TYPICAL BENT

MISSOURI PACIFIC RAILROAD BRIDGE OVER ARKANSAS RIVER WICHITA, KANSAS

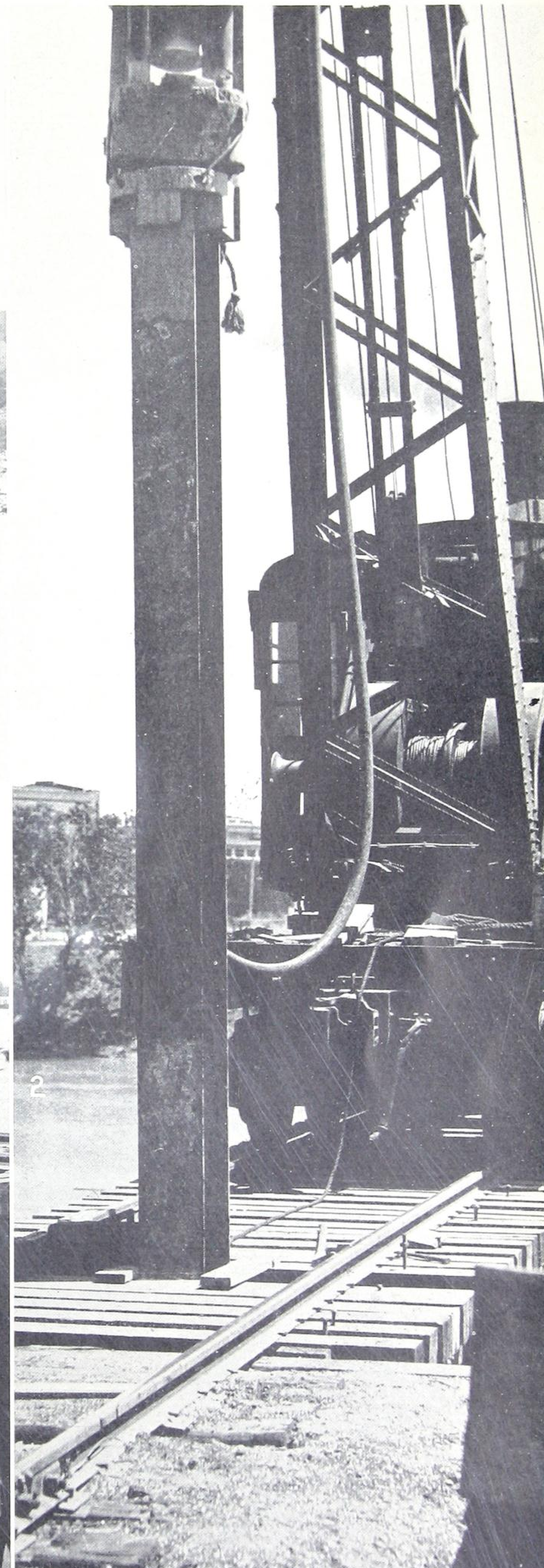
DESIGNED BY
ENGINEERING DEPARTMENT
MISSOURI PACIFIC R. R. CO.
ST. LOUIS, MO.

SEE PHOTOGRAPHS ON OPPOSITE PAGE

1. STEEL BEARING PILE TRESTLE BENTS WITH CONCRETE CAPS AND CONCRETE ENCASEMENT.
2. DRIVING CENTER PILE OF BENT. ONLY ONE TIE REMOVED TO PERMIT DRIVING. NOTE SIMPLE SIDE GUIDES.
3. DRIVING OUTSIDE PILE OF BENT. NOTE SIMPLE GUIDE FRAMES BUILT UP OF MATERIAL AVAILABLE ON JOB.

STEEL BEARING PILES INSTALLED WITH MINIMUM DISTURBANCE TO EXISTING STRUCTURE.


1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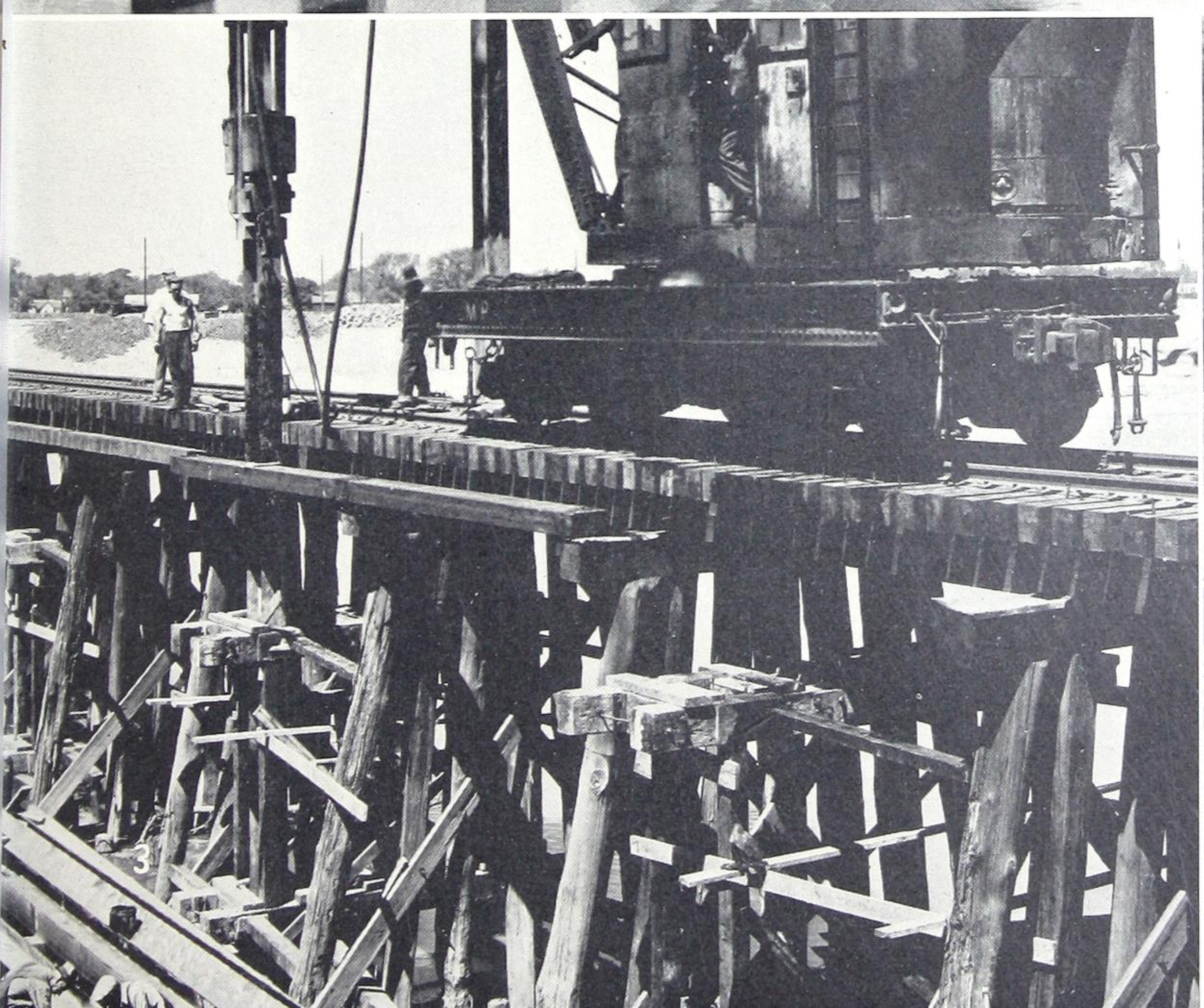
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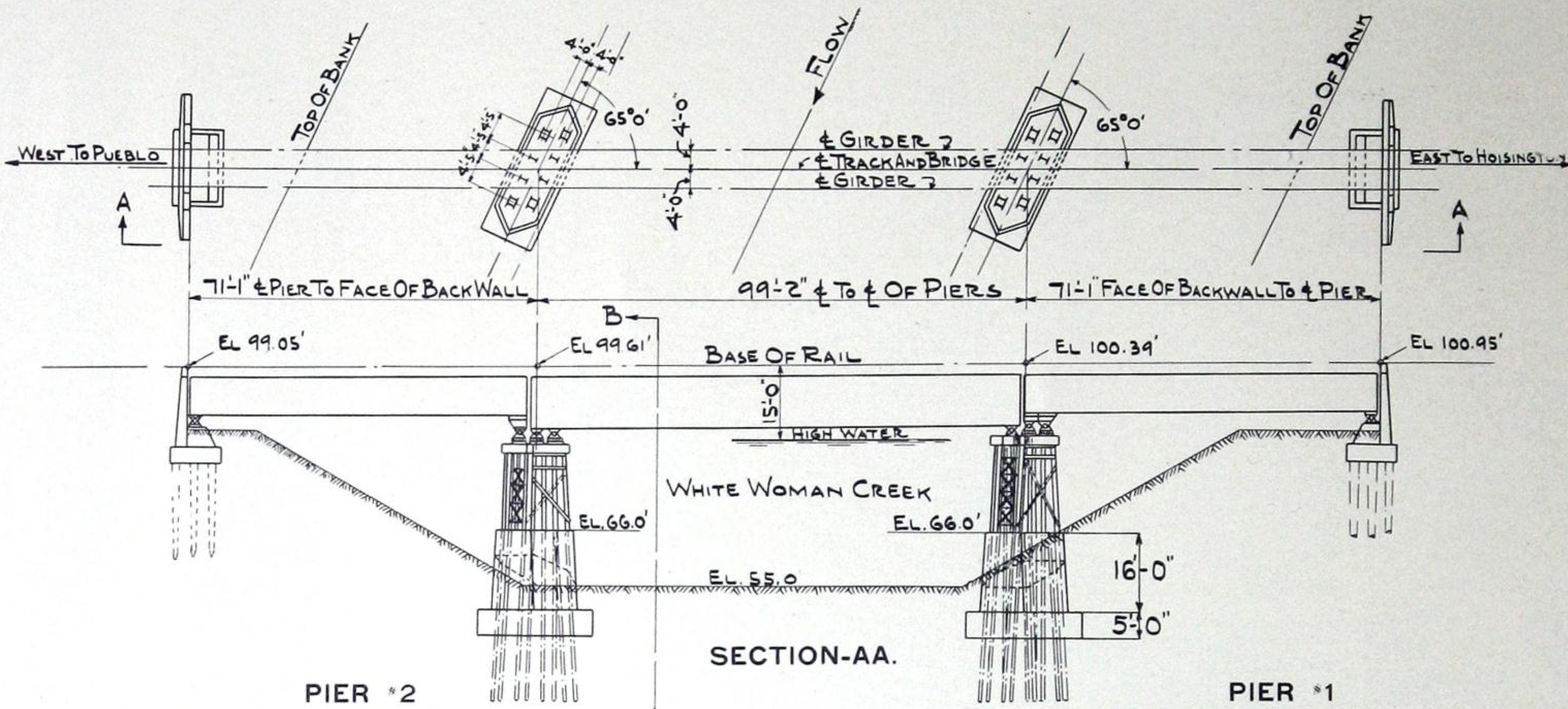
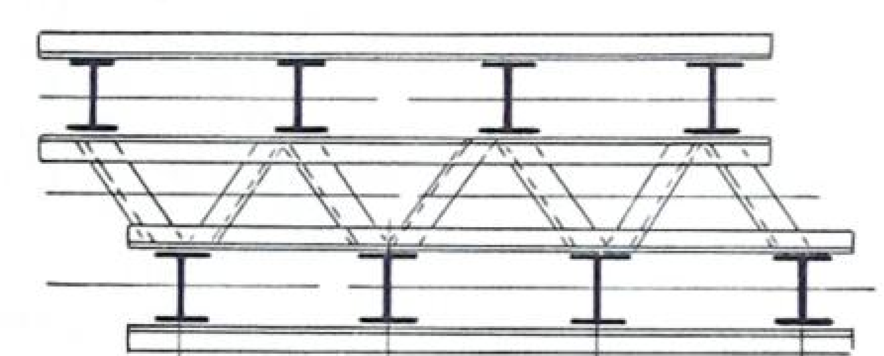


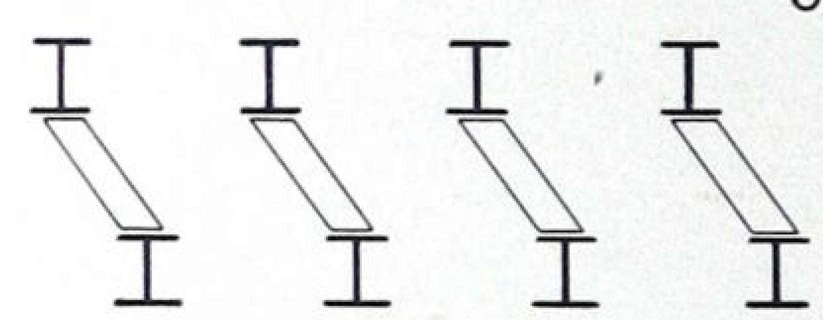
SECTION-AA.

PIER *2
8-16" CB 83 LB PILES
ORDERED 60', CUT OFF TO 59'

PIER *1
8-16" CB 90 LB PILES
ORDERED 65', CUT OFF TO 59'



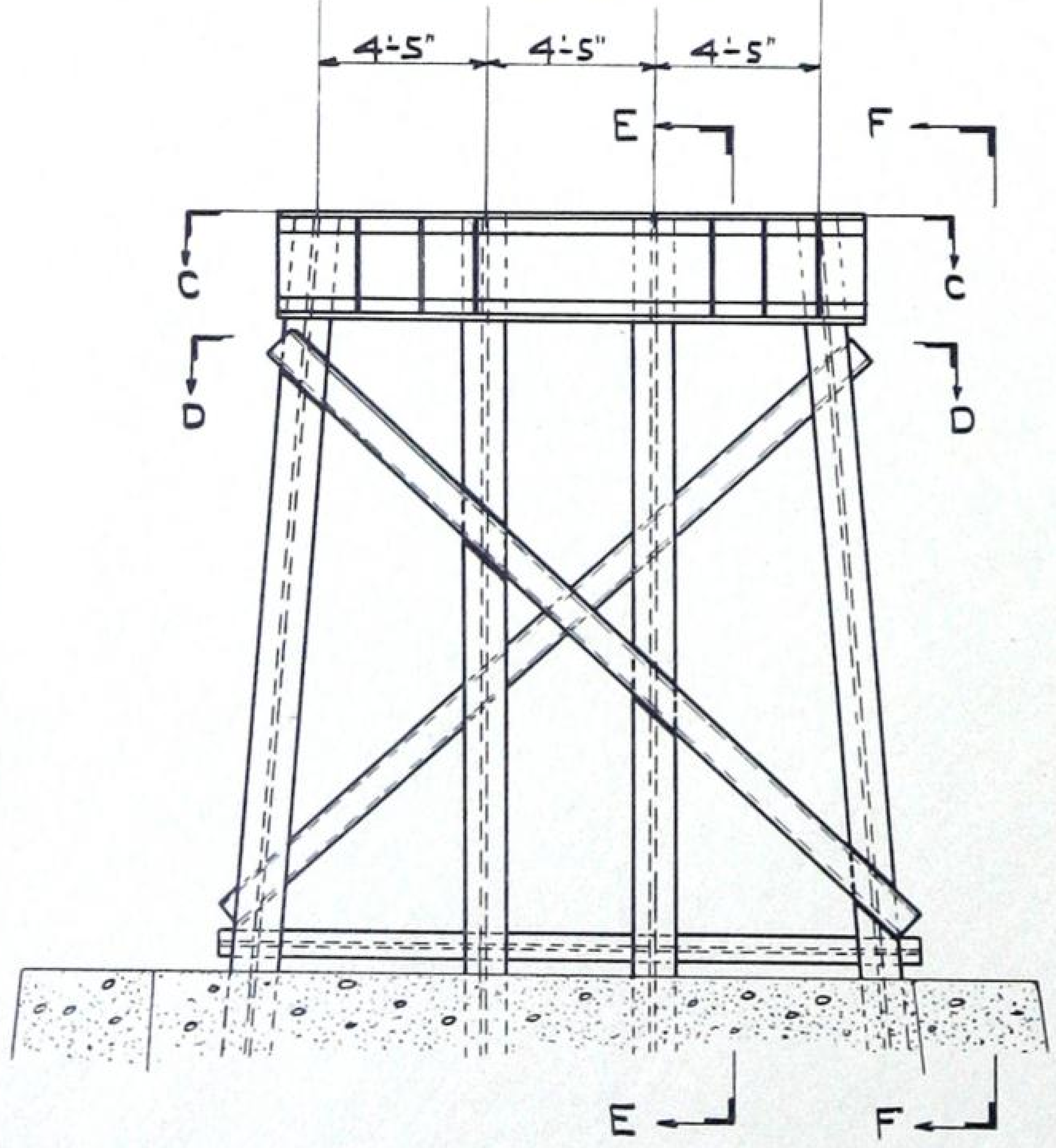
SECTION-CC.



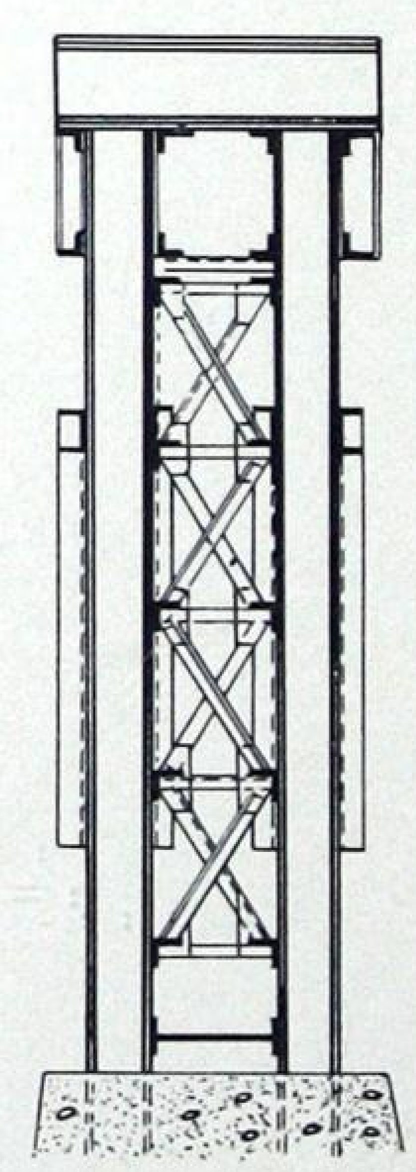
SECTION-DD.

PILES DRIVEN THROUGH CLAY, CLEAN WATER-BEARING SAND AND GRAVEL INTO FIRM SHALE.

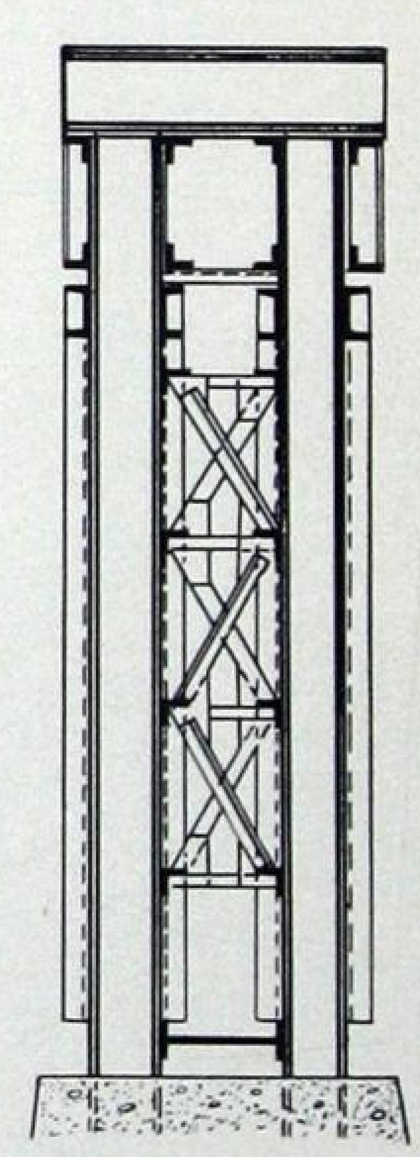
CLOUDBURSTS OCCUR WITH 15' TO 20' FLOW OF WATER. THERE IS SCOUR TO A DEPTH OF 56' BELOW BASE OF RAIL.



ELEVATION



SECTION-EE.



SECTION-FF

DESIGNED BY
ENGINEERING DEPARTMENT
MISSOURI PACIFIC R.R. CO.
ST. LOUIS, MO.

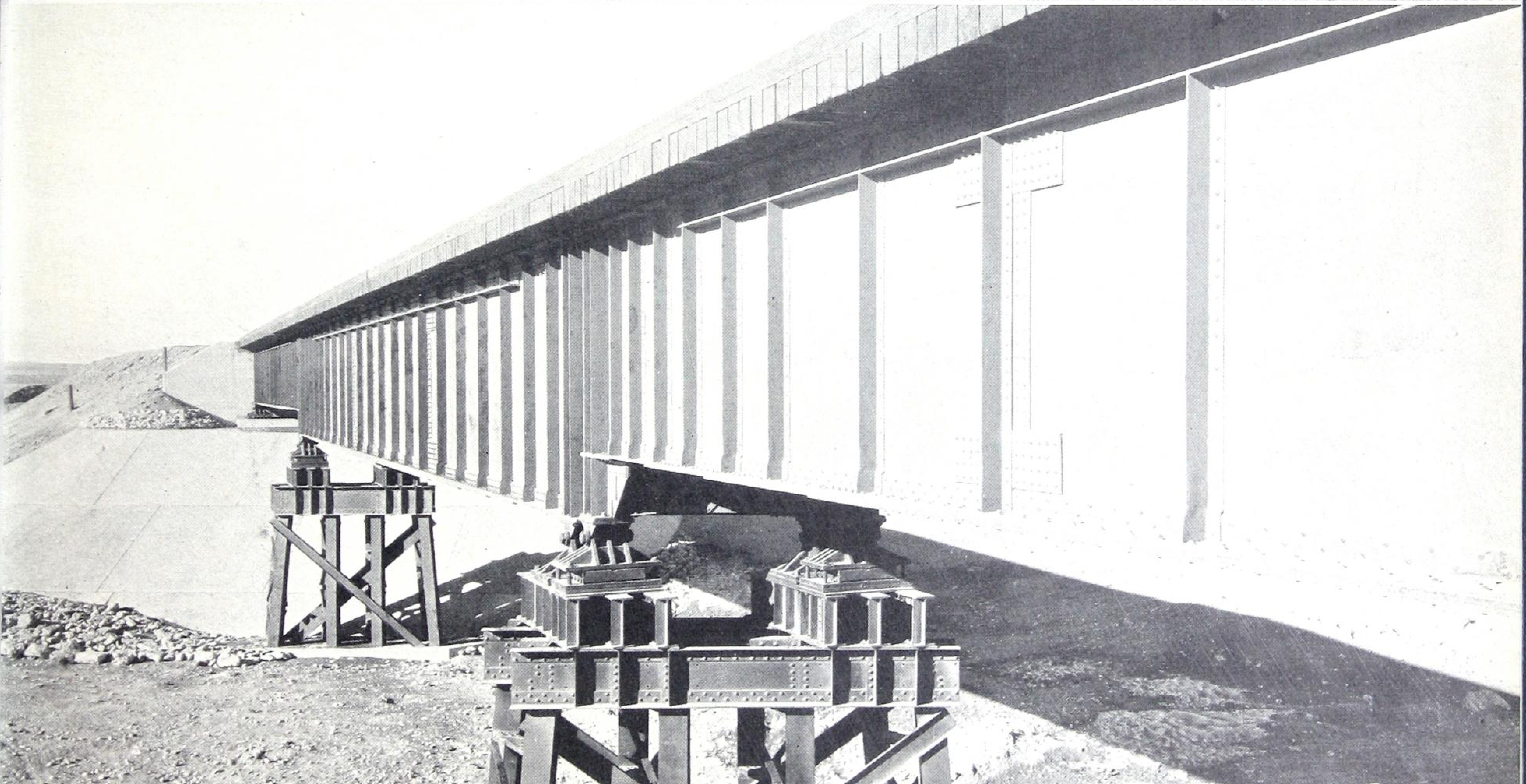
MISSOURI PACIFIC R.R. CO.
COLORADO DIVISION
BRIDGE No. 426

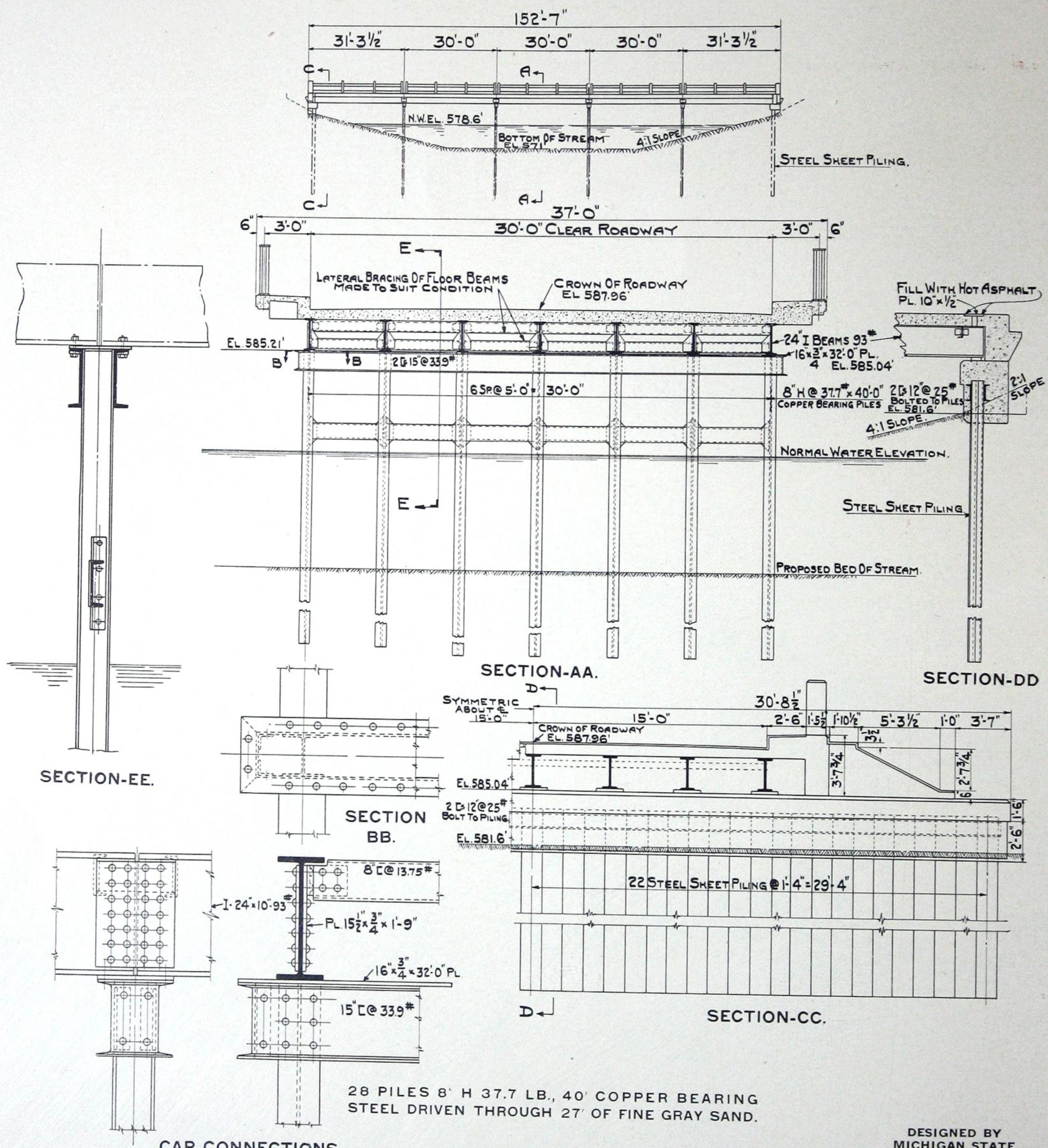
3.02 MILES EAST OF SELKIRK, KAN.

SEE PHOTOGRAPHS ON OPPOSITE PAGE

STEEL PILES WERE REQUIRED ON THIS PROJECT IN ORDER TO SECURE DEPTH OF PENETRATION NECESSARY TO PROTECT AGAINST SCOUR.

1. GENERAL VIEW OF BRIDGE.
2. DETAIL OF STEEL BEARING PILE EXTENDING ABOVE GRADE TO FORM CROSS-BRACED STRUCTURAL STEEL PIER.





28 PILES 8" H 37.7 LB., 40' COPPER BEARING
STEEL DRIVEN THROUGH 27' OF FINE GRAY SAND.

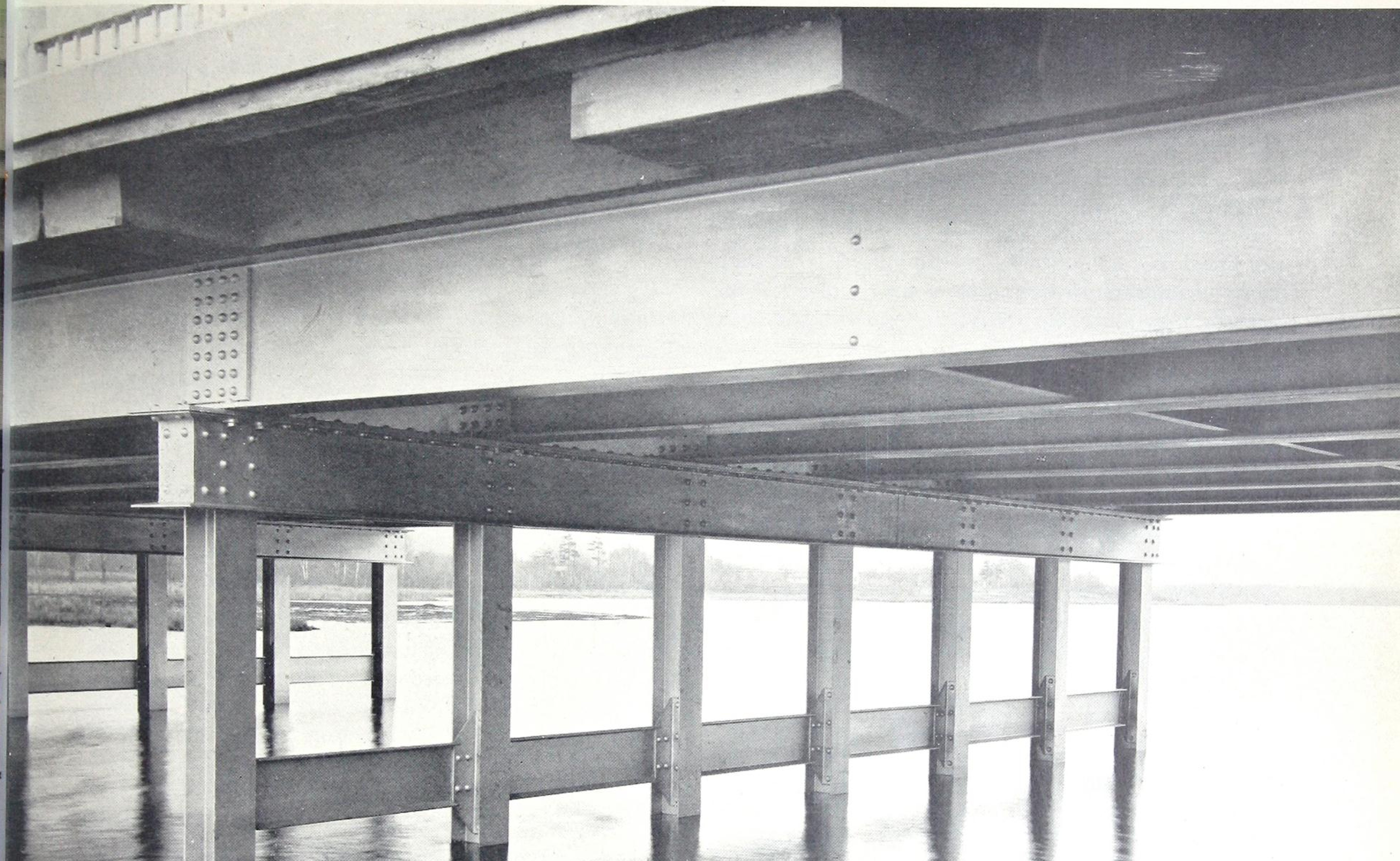
CAP CONNECTIONS.

DESIGNED BY
MICHIGAN STATE
HIGHWAY DEPARTMENT

BRIDGE CROSSING LINCOLN LAKE
MASON COUNTY, MICHIGAN

SEE PHOTOGRAPHS ON OPPOSITE PAGE

1. NOTE CLEAN CUT APPEARANCE AND BEAUTIFUL SYMMETRY OF EXPOSED STEEL WORK.
2. VIEW DURING CONSTRUCTION. NOTE SIMPLICITY OF DETAIL AND ABSENCE OF ALL TEMPORARY FALSEWORK AND CRIBBING.
3. GENERAL VIEW OF BRIDGE.


1


3

SUGGESTED SPECIFICATIONS FOR STEEL BEARING PILES

Description:

All piles shall be Carnegie Steel Company or Illinois Steel Company rolled steel CBP sections or CB sections of the section number, size and weight per lineal foot as indicated on the plans. Piles shall conform at time of driving to camber and sweep as permitted by allowable mill tolerances.

Material:

The material in rolled steel piles and splices shall be standard structural grade open-hearth steel, conforming to A. S. T. M. Standard Specifications for Bridges A7-34.

Where a considerable portion of the pile structure is exposed to the atmosphere, such as in the case where a pile also forms part of a trestle bent, it is well to add the following clause to the steel material specification: "All steel shall have a copper content of .2% minimum."

Pile Lengths:

Pile lengths for estimating purposes, as shown on the plans, are based upon probable lengths remaining in place in the completed structure. The engineer will determine the final lengths of piles required to develop the bearing values specified for the minimum penetrations acceptable, or to develop both the bearing value and minimum penetration, by means of tests specified herein.

Test Piles:

Test piles shall be driven under the observation of the Engineer.

Option (a) The contractor shall drive (here state approximate lengths indicated by test boring, soil data, local conditions, etc., for example: 3-35 foot lengths and 2-45 foot lengths of steel test piles) at the points indicated on the plans, or where and as directed by the Engineer. They shall be driven at such points that they may be left in place, cut off, and become a part of the permanent structure. From their performance under driving, the Engineer will determine the lengths of piles required.

Or (b) The Engineer shall select length and number of test piles on which loading tests shall be conducted in accordance with (here describe method, test loadings, and permissible net settlements). From the results of the pile tests, the Engineer will determine the lengths of piles required.

Or (c) The piles shall be driven to obtain a bearing power of .... tons based on the use of the following formula (here state formula), and if indicated on the plans, to a minimum depth of penetration of (depth shown).

Splicing:

Should it become necessary or desirable to splice the piles, the splices shall be made in accordance with details shown on the plans.

Welding:

In the case of welded connections, splices, etc., all work shall be done with approved methods, materials, and experienced personnel whose ability and qualifications to do acceptable welding shall be fully demonstrated to the satisfaction of the Engineer.

Bolting:

Details of bolted splices contemplate the use of milled ends on the sections of piles. Where the ends are cut by other means, the bolted splices must be proportioned to develop the full capacity of the pile on its entire cross sectional area, in order to withstand the forces encountered in driving.

If permitted by the Engineer in writing, the rough ends of pile sections may be brought into contact by means of adequate deposits of weld metal, applied between butt ends of adjacent sections after sections have been bolted in alignment.

Pile Caps:

All piles shall be cut off at elevations shown on plans and capped as indicated on the structural details. The ends of the piles shall be cut off level and surface made as smooth as practical before cap is welded in place.

Pile Bent Bracing Members:

Structural steel sway and cross bracing, and other channel and angle tie bracing, shall be placed on

steel pile bents where indicated on plans. All of this bracing material shall be welded in place as shown on plans. Where piles are not driven in the exact position and to the alignment specified, it will be necessary to use fills and shims between the bracing and the flanges of the piles. All fills and shims required to square and line up faces of flanges for cross bracing shall be furnished and placed by the contractor without cost to the owner. Weight of fills and shims used on piles will not be included in the weight of any item of structural steel paid for by the owner.

Driving:

Steel piles, including test piles, shall be driven with steam or air hammers, developing an energy per blow of not less than 7,250 ft.-lbs., nor more than 15,000 ft.-lbs. (The preceding stipulations as to hammer energy may be lowered for the lightest sections and increased for very heavy sections.) The hammer shall be operated at all times at steam or air pressures, and the speed recommended by the manufacturer.

An accurate record shall be kept of the date, time, total depth of penetration, rate of penetration and number of blows for every foot penetration under last five blows of hammer, steam or air pressure, and kind and size of hammer used in the driving. Any unusual phenomena shall also be recorded.

A cast or structural steel driving head shall be used for driving steel piles, if required, to keep the pile heads from upsetting excessively under extremely hard driving conditions.

Piles shall be driven as nearly as possible in the exact position specified on design plans; however, a maximum deviation of 1½" from exact position will be permissible in combination pile and trestle bents, and a maximum deviation of 3" from design plan position will be allowed for all piles in footings of piers or abutments. These deviations from required location will be permitted only if the contractor at his own expense widens the footing so that the minimum distance from face of pile to face of cap is not less than 3". Care shall be taken during driving to prevent and correct any tendency of the steel piles to twist or rotate.

The rows of piles around the perimeter of the bases or footings shall be driven before those in the middle.

Piles shall be driven and sunk vertically or to the batters shown by the plans. For batter piles, the pile driver leads shall be inclined so as to be in line with the desired position of the piles.

Piles shall be driven for their full effective length. Excavation below the bottom of concrete footings will not be permitted.

Pile drivers shall have firmly supported leads extending down to the lowest point the hammer must reach; short leads suspended from a line and braced only by lines will not be acceptable unless the piles are rigidly braced and held in alignment by suitable guide frames. Under-water hammers may be used only where held in rigid leads extending to full depth.

Jetting shall not be permitted unless special permission has been given in writing by the engineer.

If the material be such that cavities remain about the piles after driving, the cavities shall be filled with sand or other approved material, deposited with water.

Protective Encasement:

Concrete—

(a) After driving piles, an encasement of (here specify dense concrete mix) vibrated concrete .... inches thick measured from the extreme exterior projection of steel surfaces shall be placed, extending .... feet above and .... feet below grade or mean high or low water level.

Or (b) If permitted by the engineer, in writing, the contractor may apply a gunnite concrete to the piles before driving. This gunnite must be reinforced with an approved mesh wrapped around the pile and spaced at least one inch away from the steel surfaces. The protection shall be applied so that after driving is completed it will extend over the full lengths of zone or zones for which a protective encasement is specified.

Combination Types—

These should be specified by a comprehensive description of the method desired and by reference to complete details on the drawings.

Basis of Payment:

Use suitable paragraph from following group:

(a) Payment for steel bearing piles will be considered as completely covered by the contract price

per pound for the steel piling in place, which will include all material, tools, equipment, labor and work incidental thereto. Estimates will be made on the basis of the theoretical weight of metal in beam sections which remain as a permanent part of the structure after cut-off is removed, and will not include weight of cut-off, splices, caps, or other miscellaneous materials. Payment for cut-offs, or other waste material, and for splices including all material necessary for making splices in accordance with design details shall be considered as completely paid for under estimates made in accordance with preceding paragraphs.

(b) Payment for steel bearing piles will be made at a price per lineal foot for the length of pile extending below the bottom of the cut-off line indicated on the plans. The length of pile ordered shall provide suitably for variation of depth, and for cut-offs—and the part of pile cut off will be paid for at the cost per lineal foot of the pile delivered at the site before driving as determined by the Engineer. The prices per lineal foot applied to piles driven on a batter shall be the same as piles driven vertically. The prices so paid for piles shall cover and include all material, plants, equipment, tools, and work incidental to furnishing and preparing the permanent structure.

Splices will be paid for at the price of (here state price per splice), which price shall include full compensation for furnishing all materials, labor, tools, and equipment required to construct one splice in accordance with the details shown on the plans. No splices will be permitted in piles less than 25 feet in length, and not more than one splice will be permitted in any pile under 40 feet long.

(c) Payment for steel bearing piles will be made at a price per lineal foot for the length of pile ordered into the driving leads by the Engineer. [Balance of this paragraph made up of suitable clauses from (a) or (b).]

(d) Measurement of pay quantities for furnishing steel piles will be based on the lengths of piles ordered by the Engineer, and no deductions will be made for cut-off lengths. [Balance of this paragraph made up of suitable clauses from (a) or (b).]

(e) Payment for (here state number) pile tests as specified in section or paragraph .... shall be considered as covered by the contract price for piling in place.

(Or) Payment for pile tests as specified in section or paragraph .... shall be made at the rate of (here state lump sum) for test for each complete test ordered by the Engineer.

Additional data will be collected as the use of CBP sections is extended. Our Engineers can give you the benefit of their wide experience. When you have a problem involving bearing piles, please consult a Carnegie Steel Company or Illinois Steel Company representative at the nearest district office.

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BLAST FURNACE PRODUCTS

Basic Pig Iron
Bessemer Pig Iron
Ferro-ManganeseⒸ

Ballast SlagⒸ
Bank Slag
Concrete SlagⒸ

Road Building SlagⒸ
Granulated Slag
Sand SlagⒸ

STEEL—CLASSES AND KINDS

CARBON
Open-Hearth
Bessemer

U S S High-Tensile Steels
U S S Stainless and Heat Resisting Steels

ALLOY
Open-Hearth Alloy
Electric Carbon and Alloy①

ROLLING MILL PRODUCTS

SEMI-FINISHED PRODUCTS

Ingots
Blooms
Billets
Slabs
Sheet Bars
Skelp (Wide and Narrow)

STRUCTURAL PRODUCTS

CB Sections
Standard Beams
Light Beams
StanchionsⒸ
JoistsⒸ
H-Beams
Standard Channels
Ship Building Channels
Car Building Sections
Bulb Angles
Angles
Tees
Elevator TeesⒸ
Conductor TeesⒸ
Zees
Cross Tie SectionsⒸ
Steel Sheet Piling
Miscellaneous Sections

PLATE PRODUCTS

Sheared Plates—
  Rectangular
  Circular
  Sketch
Universal-Mill Plates
Base Plates for Columns and
  Machinery
Floor Plates

FABRICATED PRODUCTS

Steel Mine TimbersⒸ
Gangway Sets and Mine PropsⒸ
Steel Sheet Piling
H Bearing Piles
I-Beam-Lok Floor
  ConstructionⒸ
T-Tri-Lok Floor ConstructionⒸ

RAILROAD TRACK PRODUCTS

Standard Rails, over 60 pounds
Light Rails, 60 pounds and under
Miscellaneous Rails
G E O Track MaterialⒸ
Angle Splice Bars
Fish Plates
Tie Plates
Riser Plates①
Frog FillersⒸ
Reinforcing BarsⒸ
Screw Spikes
Track Spikes
Track Bolts and Nuts
Rail Clips
Cross Ties for RailroadsⒸ
Cross Ties for Mine TrackⒸ
Cross Ties for Portable TrackⒸ

WROUGHT AND FORGED PRODUCTS

Axles—
  Untreated
  Annealed
  Quenched and TemperedⒸ
  Electric Railway Car
  Steam Railroad Car
  Locomotive Driving
  Locomotive Trailing
  Tender
  Mine CarⒸ
  Industrial CarⒸ
  Armature Shafts—Alloy
  Armature Shafts—Carbon
Wheels—
  Solid Wrought, Carbon Steel
  Untreated
  Rim Toughened
  Quenched and Tempered①
  Electric Railway
  Steam Railroad
  Industrial CarⒸ
  Mine LocomotiveⒸ
  Industrial LocomotiveⒸ
  Crane TrackⒸ
Miscellaneous Circular SectionsⒸ
Fly Wheel Blanks for TrucksⒸ
Brake Drums for TrucksⒸ
Heavy Forgings—
  UntreatedⒸ
  Annealed Ⓒ
  Quenched and TemperedⒸ

BAR AND STRIP MILL PRODUCTS

Agricultural Implement Sections
Angles
Automobile Body Sections
Automobile Bumper Sections
Automobile Rim Sections
Barrel SectionsⒸ
Bevel Sections
Cam SectionsⒸ
Can Ring SectionsⒸ
Casement Sections
Channels
Concrete Reinforcement Bars
Cooperage Steel—
  Tight and SlackⒸ
CrescentsⒸ
Flat Blanks for Automobile
  PartsⒸ
Flats—Square Edge, Band
  Edge and Round Edge
Grooved FlatsⒸ
Half Ovals
Half RoundsⒸ
Hame SectionsⒸ
Hexagons
Hoops
Key Sections
Locking Bar SectionsⒸ
Magneto SectionsⒸ
Neck Yoke SectionsⒸ
Nut Sections
Ovals
Pipe Coupling Sections
Pole Cap SectionsⒸ
Pole SectionsⒸ
Round Cornered Squares
Rounds
Skelp—Bevel Edge and
  Scarfed
Slack Barrel Cooperage
Special Sections of Various
  Kinds
Spring Steel Sections
Squares
Strip
Tees
Window Sash Sections
Zees

COKE AND COKE BY-PRODUCTS

Blast Furnace Coke

Benzol—
  Industrial Pure
  Industrial 90%
  Motor
Toluol, Industrial Pure
Xylol, Industrial

Naphtha—
  Industrial Refined Light SolventⒸ
  Industrial Crude Light SolventⒸ
  Industrial Crude Heavy Solvent
  Industrial High TestⒸ
Ammoniacal Liquor
Ammonium Sulphate

Crude Naphthalene
Tar
Creosote OilⒸ
Cresylic AcidⒸ
PhenolⒸ
CresolⒸ

ⒸCarnegie Steel Company only. ①Illinois Steel Company only.

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ILLINOIS STEEL COMPANY

GENERAL OFFICES, CHICAGO, ILL. .... 208 South LaSalle Street

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Milwaukee, Wis .... Bankers Building, 208 East Wisconsin Avenue

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Columbus, Ohio .... American Insurance Union Citadel, 50 West Broad Street
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